COMBI

Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe

Final quantification report

D2.7

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Executive summary

This D2.7 quantification report summarises the quantification approaches applied in the COMBI project and main project findings. It therefore draws on other COMBI reports that contain this information in greater detail in order to summarise quantifications. These sources are mainly:

- D3.4 to D7.4 quantification reports for impact quantifications
- D2.4 report on synthesis methodology
- D8.1 online tool manual and documentation
- Quantified impacts as available from the COMBI online tool

The report is structured in 3 main sections:

1. The COMBI approach and methods, explaining key methodological approaches both for individual impact quantifications and for the aggregation of impacts
2. Quantification results, giving an overview on main figures of quantified indicators and
3. Insights from cross-impact analysis, which gives a comparison between monetised impacts and presents their use for Cost-Benefit calculations in the COMBI online tool

Important note: This report does not include all possible graphical and numerical values and analyses quantified by the project. All visualisations and data can be retrieved from download options of the online tool.

COMBI approach and methods of MI quantification

In principle, any energy efficiency impact evaluation can be done from different analytical perspectives, e.g. the investor/end-user perspective, program administrator perspective or the societal perspective. COMBI applies the "societal perspective", as this is most relevant for policy-making.

COMBI draws on a reference scenario until the year 2030 including existing (partially already ambitious) policies. By modelling 21 sets of "energy efficiency improvement" (EEI) actions, a second efficiency scenario was modelled amounting to additional energy savings of around 8% p.a. in 2030, that is comparable to the EUCO+33 to EUCO+35 scenario.

All figures quantified by COMBI relate to *additional* or *incremental* values, i.e. *additional* impacts resulting from *additional* EEI actions beyond the reference scenario.

The project quantified in total 31 individual impact indicators spread across 5 Work Packages, each of which applied appropriate, specialised and state-of-the-art models. Covered impacts include

- air pollution with sub-effects on
  - ecosystems
  - human health
- energy poverty-related health impacts from building conditions
- productivity impacts from residential and tertiary building refurbishments
- resource impacts (material footprint, including various sub-impacts)
- macro-economic impacts (labour market, GDP and public budgets)
- energy system/security impacts (various indicators)

More than half of all sub-indicators were possible to monetize, but not all monetized impacts can automatically be included to a Cost-Benefit Analysis (CBA), because they may possibly overlap. COMBI thus followed the impact pathway approach developed by the ExternE project to identify possibly overlaps. Where the research team identified some, we entirely excluded impacts from the CBA. This leads to an underestimation of total impacts, because (entirely) excluded impacts are certainly partially additional. However, as a separate assessment of adjustment factors was not possible within this project, this presents very conservative figures, that however can be interpreted as low end of the scale.

While full analysis on sensitivities of all kinds in all models applied was not possible (almost infinite number of sensitivities), the research team decided to include two options for users of the online tool to directly test CBA results for sensitivity on two variables:

- Energy price scenarios (deviating ±10% from the COMBI forecast)
- Discount rates directly entering the CBA calculation formula (COMBI standard rate at 3%, option for user to apply different rates of 0–10%)

Key quantification results

Pursuing a more ambitious EE policy that leads to achieving the COMBI efficiency scenario relative to the COMBI reference will lead to **at least** (conservative estimation):
(selected impacts, per year)

- Avoided health problems: in total, 260,000 DALYs/year, 17,000 deaths/year
- Additional labour productivity: 39mn workdays/year
- Lower material footprint: More than 850 Mt resource savings (production phase not accounted for in most cases)
- Avoided investment in electricity generation: 10bn€/year
- Lower fossil fuel import costs: 60bn€/year
- Up to 160bn€ additional GDP corresponding to 0.9 per cent of EU's GDP (in case of negative output gap)
- Up to 85bn€ public budget effect (in case of negative output gap)
- Positive effect on the labour market: up to 2.3mn person-years additional employment (in case of negative output gap)

If including only those monetized impacts to a cost-benefit analyis where COMBI is entirely sure that no overlaps exist, the analysis yields that

- MI amount to approx. 50% of energy cost savings when looking at all actions (excl. modal shift and trucks)
- MI amount to approx. 70% of energy cost savings for the residential buildings refurbishment example

Economic impacts (aggregate demand/GDP and public budget) are not included due to *partial* overlaps (that could not be quantified).

1 The COMBI approach and methods

1.1 Evaluation perspective

For any evaluation of multiple impacts, the perspective of the assessment needs to be defined, both in terms of which groups of stakeholders to account for and in terms of the geographic scale. This section focuses on the groups/types of stakeholders to consider in the analysis.

One standard reference for these "evaluation perspectives" are the five different cost-effectiveness tests developed in the US by CPUC. These "cost-effectiveness tests" consider the different components relevant for each perspective and thereby provide different information for decision makers (NAPEE 2008) – for more details see Table 6 in the Annex:

For COMBI, theoretically three evaluation perspectives are relevant:

1. **End-use actor perspective (CPUC: PCT)**
2. **Societal perspective (CPUC: SCT)**
3. **Public budget perspective (CPUC: PACT for government but only cost side without lost revenues)**

End-use actor/investor perspective: The perspective of the energy consumers or investors indicates whether the energy efficiency actions are cost-effective for such end-user actors. (Incremental) costs of the end-use actions are considered, while the (additional) energy cost savings over the action lifetime are counted as benefits. In addition, there can be non-energy benefits or costs. Higher benefits (energy alone or incl. others) than costs indicate that end-user actors have economic incentives for implementing an action, often taken as a precondition for investing in the respective action. In COMBI, financial incentives (like tax, subsidy etc.) are not assessed (at least not comprehensively) as the focus is on the analysis of end-use actions, not on the impact of policies or programmes. Also, other hidden costs such as transaction costs are not quantified. Therefore, an end-user evaluation has not been carried out within COMBI.

Societal Perspective: In CBA, societal costs and benefits are equal to the sum of all individual costs and benefits. Where a measure imposes costs on one group of individuals and results in a corresponding and equal benefit to another group then from a societal perspective, these costs and benefits cancel out and are considered a transfer between different groups with no overall impact on societal welfare, therefor impacts are quantified net of taxes and transfers. From a societal perspective, only those costs and benefits count, which are not simple transfers but have an impact on the well-being of society as a whole.

Public budget perspective: Impacts can also be evaluated from the perspective of the public budget (treasury). If policies or programmes are funded from public budget, there are programme costs including financial incentives, overhead costs, and installation costs. In addition, reduced energy tax revenues of the government through decreasing energy sales and increased tax revenues from technology sales as well as relevant monetary impacts should be taken into account on the cost side when evaluating the net public budget impact. Benefits include energy cost savings for public operations (if any), reduced energy subsidy payments (if existent), additional corporate and value added tax (VAT) revenues due to induced investments and turnover (if any), and additional income tax revenues as well as reduced unemployment expenses (if employment increases). In addition, from various multiple impacts, effects on public budgets are possible, such as reduced public health spending, decreasing external costs for environmental degradation (e.g. soil, climate change adaptation).

The COMBI approach

In early stages of the project, all three relevant evaluation perspectives were pursued. Due to resource constraints, only the evaluation perspective most relevant to policymaking is being studied in detail and included in all reports and the COMBI online tool: the **societal perspective**. However, the investor/end-user perspective can also be partially evaluated as information on energy cost savings, investment costs and many of the effects are studied and available also incl. taxes. The public budget analysis is not studied as separate perspective but treated as one impact studied in WP6, albeit with a methodologically limited approach not accounting for the manifold impact chains on public finances.

1.2 COMBI energy efficiency actions and scenarios

COMBI energy improvement actions

The COMBI research team intended to cover a wide range of efficiency improvement, but as the sum of individual improvements often is not equal to the implementation as one consistent set of actions and even in many cases not the recommended way, we decided to depart from the concept of energy services, analysing technical sub-actions in a "whole system approach". For example, for space heating the entire system would consist of the location (climate zone) and orientation of the building, its compactness, the building shell (thermal insulation, airtightness), the heating, cooling and ventilation system, and the daylighting system. An interplay/combination of different behavioural actions ("best practices") and technical actions ("more efficient technologies") thus leads to an overall energy efficiency improvement of the system as a whole.

In this sense, 21 energy efficiency improvement (EEI) actions have been defined, each containing a number of technical (and sometimes to a certain level behavioural) options, following the selection criteria of

1. Use *energy services* as a starting point (i.e. not start from technical appliances, but from services such as "heating/cooling" or "mobility");
2. Use *existing EU energy scenarios* as a reference;
3. Focus on *technical* improvements;
4. Cover *80% of the EU end-use energy saving potential*.

COMBI actions cover the sectors of buildings, transport and industry. The selected COMBI actions are described in detail in the D2.2 report. Table 1 gives an overview.

Table 1: List of selected end-use technical energy efficiency improvement actions for the COMBI project

#	End-use energy efficiency action
Action 1	residential refurbishment of the building shell + space heating + ventilation + space cooling (air-conditioning)
Action 2	residential new dwellings
Action 3	residential lighting (all dwellings);
Action 4	residential cold appliances (all dwellings);

#	End-use energy efficiency action
Action 5	non-residential refurbishment of building shell + space heating + ventilation + space cooling (air-conditioning)
Action 6	non-residential new buildings
Action 7	non-residential lighting (all buildings)
Action 8	non-residential product cooling (all buildings)
Action 9	passenger transport – modal shift
Action 10	passenger transport – motorized two-wheelers
Action 11	passenger transport – car
Action 12	passenger transport – bus
Action 13	freight transport – modal shift
Action 14	freight transport – light duty truck (LDT)
Action 15	freight transport – heavy duty truck (HDT)
Action 16	industry (7 sectors) - high temperature process heating
Action 17	industry (7 sectors) - low and medium temperature process heating
Action 18	industry (7 sectors) – process cooling
Action 19	industry (7 sectors) – specific process electricity
Action 20	industry (7 sectors) – motor drive
Action 21	industry (7 sectors) – HVAC in industrial buildings

COMBI scenarios

COMBI provides estimates of the major multiple impacts of the energy efficiency potential that goes beyond an existing policies scenario in the year 2030. Impacts are quantified by EU member state and by single energy efficiency improvement (EEI) action. Therefore, detailed input data on energy savings and investment costs are necessary: COMBI uses detailed stock models to this end. The COMBI input data modelling exercise produced a baseline scenario (based on existing EU legislation) and an efficiency scenario (based on ambitious assumptions on technology implementation following more ambitious policies), comparable to the **EUCO+33 to EUCO+35 scenario** of the EU EED impact assessment.

Given the unexpected unavailability of detailed information from existing EU energy scenario studies, a new set of energy system models was developed by COMBI. These models had to include proper, detailed “stock analysis” of technologies, as this was required by the COMBI partners as input for their impact quantifications, especially for work package four (resources) and five (building-related health and productivity impacts). Furthermore, the use of Visual Basic for Applications (VBA) in MS EXCEL added much needed flexibility in the actual modelling of the different energy systems. The use of stock analysis led to the added burden that scenarios had to be defined in terms of “percentage share of annual new sales for energy efficient technologies”, rather than in terms of “market share of an energy efficient technology in a particular year”. As this type of information is rarely available, if at all, a lot of original and very time-consuming work had to be done constructing the various COMBI scenarios.

The aforementioned COMBI models were consequently used to calculate “reference” and “energy efficiency” scenarios, for each of the COMBI actions and for each individual EU member state. The results were transferred to the other COMBI partners for evaluation and use in their respective models.

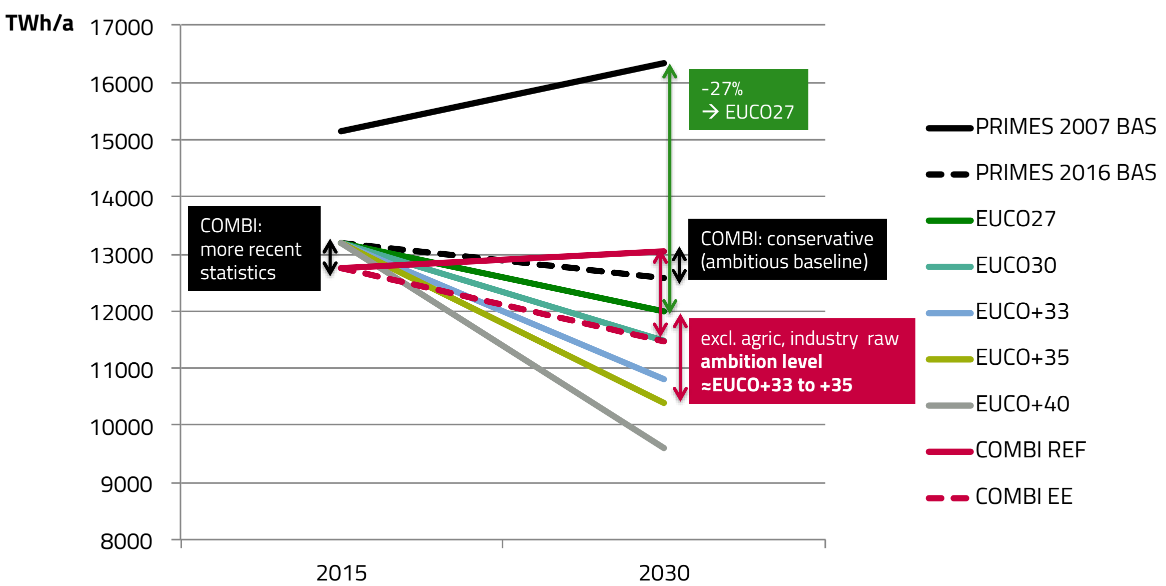
1.3 Quantifying incremental savings and impacts

The difference between the baseline and efficiency scenario is used as input data (i.e. incremental energy savings and investment costs) for quantifying multiple impacts. These results were transferred to the other COMBI partners for evaluation and use in their respective models. Also, only incremental multiple impacts are quantified. This means, **COMBI quantifies the additional multiple impacts of more ambitious policy action**. One goal of COMBI scenarios and impact quantification was to provide a bottom-up funding of the scenarios modelled for the EU-Commission's EED Impact Assessment and its annexes (based on PRIMES et al.).

However, there are some major differences in the modelling techniques and the two (COMBI/EED-IA) approaches are not fully comparable, mainly due to

- COMBI focusing on energy efficiency only vs. EED-IA analysing multiple targets (GHG reductions, renewables, energy efficiency)
- COMBI based on detailed stock model of technologies analysing incremental EEI actions (without cost optimization) vs. EED-IA based on cost-effective target achievement using PRIMES/E3Mlab/ICCS/GAINS et al.
- COMBI covering a limited set of 21 EEI actions in sectors buildings, transport, industry (thus only a share of the full potential) vs. EED-IA covering all sectors and the full potential (incl. supply and demand)

As a consequence, scenarios cannot be fully comparable, but COMBI provides a much more detailed (by EEI action and EU-member state) disaggregation of energy savings and costs, while covering only a share of the full potential. Overall, the COMBI efficiency scenario approximates the "EUCO30" scenario of the EU-Commission's EED Impact Assessment, but in terms of level of ambition and if covered actions would be extended, the COMBI scenario would be around the "EUCO+33" to EUCO+35 scenario.



[Details on scenario comparison and data summary]

1.4 Methods for multiple impact analysis

The COMBI project quantifies different multiple impacts (MI) of energy efficiency improvement (EEI) actions, which require different type of assessment approaches (methodologies). In addition, many of the impacts overlap with each other either due to estimation techniques or theoretically, which makes their aggregation challenging. In addition, different impacts are quantified in different units, rendering aggregation impossible until and unless a common unit is found. Therefore, there is a need for an overarching aggregation methodology in order to incorporate quantified impacts into a decision-making framework such as cost-benefit analysis.

In the COMBI project, for each impact end-point, physical metrics are quantified, and then according to the physical metric, monetization is be done where possible.

The steps below are followed in order to accurately measure and aggregate multiple impacts:

1. Identify the impacts and root causes of the impacts explicitly
2. Identify the causal effects of an impact i.e. whether the impact results in another impact
3. Choose significant end-points
4. Quantify the incremental impacts in physical units
5. Monetize the physical value
6. Aggregation of impacts
7. Incorporate the monetised value in a decision-making analysis such cost-benefit analysis (CBA) and/or marginal abatement cost curve (MCA)

COMBI uses the impact pathway approach (see section 1.6) in order to identify the interactions among the impacts and also in order to understand the causal effects of impacts in a detailed manner.

In the following, the quantification methodologies of the different work packages are described briefly. The models are always used for quantifying the respective impacts due to accelerated energy efficiency improvements in the year 2030.

In **work package 3 (air pollution)** the following impact indicators are quantified: the mid-points air pollution and following from that the end-points human health (various indicators), eco-systems acidification and eutrophication.

Air pollution emissions (mid-points) are outdoor air pollutants emissions from energy production and transportation. Human health describes premature mortality due to the exposure of different outdoor pollutants. By eco-systems acidification the total ecosystem area spared from acidification is meant. Eco-systems eutrophication refers to the total ecosystem area spared from eutrophication.

For the quantification of the impact indicators in this work package, the GAINS model (Greenhouse Gas - Air Pollution Interactions and Synergies model) is used. For more information on the methodology see D3.4 report, and specifically on the GAINS model see D3.4, p. 13 (Box).

In **work package 4 (resources)** the following impact indicators are quantified: material footprint (including minerals, biotic raw materials, unused extraction), life-cycle wide fossil fuel consumption, direct carbon emissions and carbon footprint (incl. emissions upstream the energy provision chain).

Material footprint describes the sum of extracted abiotic (fossil fuels, metal ores, minerals) and biotic raw materials from nature, including the extraction of materials not used further. Life-cycle wide fossil fuel consumption accounts the material flow of all raw materials from nature, that can be classified as fossil fuels and are put to an economic use (Material Flow Accounting). Under minerals the material flow of all raw materials from nature that can be classified as minerals and are put to an economic use, is subsumed. The indicator biotic raw materials encompasses those materials which can be classified as biotic raw materials and are put to an economic use. Under unused extraction the materials that are extracted from nature but are not translocated from site or put to an economic use is understood (Material Flow Accounting). This includes overburden and by-catch as well as waste on site. Direct carbon emissions are based on emission factors for different fuel types found in the IPCC reports. Values are listed in CO_2 equivalents per unit of energy. A life-cycle assessment of characterised greenhouse gases and their global warming potential in 100 years (GWP 100a) is accounted as carbon footprint. Characterisation factors are based on the IPCC reports.

Methods for calculation are Material-Input-per-Service (MIPS) (for more information and sources see D4.4).

In **work package 5 (social welfare)** the following impact indicators are quantified:

For energy-poverty related impacts: Excess winter mortality attributable to inadequate housing, excess winter morbidity attributable to inadequate housing, indoor dampness, active days and workforce performance. The indicator excess winter mortality refers to the premature mortality due to inadequate heating and cooling. Excess winter morbidity describes the premature morbidity due to inadequate heating and cooling. The indicator indoor dampness/asthma signifies asthma incidence due to dampness in the building.

For productivity impacts: the indicator active days (impact through health-asthma, allergy, cardiovascular disease, cold and flu and traffic time saved) bases on an indoor dose-response model to calculate the indoor exposure-related active days and basic reduction method is used to calculate congestion-related active days. For the indicator workforce performance the basic performance improvement equation is used to calculate workforce performance.

For more information on energy poverty-related methods see D5.4 report.

For more information on productivity-related methods see D5.4a report.

In **work package 6 (macro-economic impacts)** the following impact indicators are quantified: Temporary (business-cycle) employment, temporary (business-cycle) public budget effects, fossil fuel price effects, ETS price effects, Terms of Trade effect and sectoral shifts.

For both the quantification of temporary (business-cycle) employment and temporary (business-cycle) public budget effects input/output analysis and fiscal multiplier analysis are used. The fossil fuel- and the ETS price effects as well as the Terms of Trade effect and sectoral shifts are quantified via general equilibrium modelling (Copenhagen Economics Global Climate and Energy Model - CECEM). For more information on methods used for macro-economic impact estimation, see D6.4 report.

In **work package 7 (energy security)** the following impact indicators are quantified: energy intensity, import dependency, aggregated energy security, avoided electric power output & investment costs and derated reserve capacity rate.

The quantification of the indicator energy intensity results from the final energy demand reduced by COMBI actions (WP 2) divided by GDP. Import dependency is accounted via COMBI Energy balance model. Main input is final energy demand reduced by COMBI actions (WP 2). The relevant output is net imports. Net imports of fuels multiplied by their respective energy prices. For the quantification of aggregated energy security the COMBI Energy balance model is also used. The relevant output are net imports. Subsequently an allocation model is applied to determine the origin of imports. Additionally risk indicators are used to assess political risks. Avoided electric power output & investment costs are also quantified with the COMBI Energy balance model. By means of a power sector model the mix of power plant and cogeneration plant technologies and capacities are determined. Relevant output is net power output. Avoided power output multiplied by specific capital costs per technology results in avoided investment costs. To quantify the derated reserve capacity rate again the COMBI Energy balance model and power sector model are utilised to determine peak loads and required reserve capacities based on annual load duration curves.

For detailed information on the energy balance model and quantified impacts see D7.4 report.

Table 2: Summary of quantification methodologies

Work packages	Impact indicators	Description of the quantification methodology
WP3: Air pollution D3.4	Human health	Premature mortality due to the exposure of different outdoor pollutants by using GAINS model
	Eco-systems: acidification	Total ecosystem area spared from acidification by using GAINS model
	Eco-systems: eutrophication	Total ecosystem area spared from eutrophication by using GAINS model
	Air pollution: Emissions(mid-points)	Outdoor air pollutants emission from fuel combustion and transportation by using GAINS model
WP4: Resource D4.4	Material Footprint (sum fossil fuels, minerals, biotic, unused)	The Material Footprint is the sum of extracted abiotic (fossil fuels, metal ores, minerals) and biotic raw materials from nature, including the extraction of economic unused materi-als. Quantified using Material Flow Accounting.
	Life-Cycle wide fossil fuel consumption	Accounting (Material Flow Accounting) of all raw materials from nature, that can be classified as fossil fuels and are put to an economic use.
	Minerals	Accounting (Material Flow Accounting) of all raw materials from nature, that can be classified as minerals and are put to an economic use.
	Biotic raw materials	Accounting (Material Flow Accounting) of all raw materials from nature, that can be classified as biotic raw materials and are put to an economic use.
	Unused extraction	Accounting of materials that are extracted from nature (Ma-terial Flow Accounting), that are not translocated from site or put to an economic use. This includes overburden and by-catch as well as waste on site.
	Direct carbon emissions	Direct carbon emissions are based on emission factors for different fuel types found in the IPCC reports. Values are lis-ted in CO_2 equivalents per unit of energy.
	Carbon Footprint (GWP, lifecycle missions incl. direct emissions)	Life-cycle Assessment of characterised greenhouse gases and their global warming potential in 100 years (GWP 100a). Characterisation factors are based on the IPCC reports.
WP5: Social welfare D5.4 (energy poverty) D5.4a (productivity)	Excess winter mortality attributable to inadequate housing	Premature mortality due to inadequate heating and cooling, quantified by dedicated modelling.
	Excess winter morbidity attributable to inadequate housing	Morbidity due to inadequate heating and cooling, quantified by dedicated modelling.
	Indoor dampness/asthma	Asthma incidence due to dampness in the building, quantified by dedicated modelling.
	Active days (impact through health-asthma, allergy, cardiovascular disease, cold and flu and traffic time saved)	Indoor exposure dose-response model is used to calculate the indoor exposure-related active days and basic reduction method is used to calculate congestion-related active days, quantified by dedicated modelling.
	Workforce performance	Basic performance improvement equation is used to calculate workforce performance, quantified by dedicated modelling.
WP6: Macro-Economic impacts	Temporary (business-cycle) aggregate demand	Input/output analysis and fiscal multiplier analysis
	Temporary (business-cycle) employ-ment	Input/output analysis and fiscal multiplier analysis

Work packages	Impact indicators	Description of the quantification methodology
D6.4	Temporary (business-cycle) public budget effects	Input/output analysis, fiscal multiplier analysis and budgetary semi-elasticities
	Fossil fuel price effects	General equilibrium modelling (Copenhagen Economics Global Climate and Energy Model - CECEM)
	ETS price effect	General equilibrium modelling (Copenhagen Economics Global Climate and Energy Model - CECEM)
	Terms of Trade effect	General equilibrium modelling (Copenhagen Economics Global Climate and Energy Model - CECEM)
	Sectoral shifts	General equilibrium modelling (Copenhagen Economics Global Climate and Energy Model - CECEM)
WP7: Energy security D7.4	Energy intensity	Final demand reduced by COMBI actions (WP2) divided by GDP
	Import dependency	COMBI Energy balance model. Main input is final demand) reduced by COMBI actions (WP2). Relevant output is net imports. Net imports of fuels multiplied by their respective energy prices
	Aggregated energy security	COMBI Energy balance model. Relevant output is net imports. Allocation model to determine country of origin of imports. Use of risk indicators to assess political risks.
	Avoided electric power output & investment costs	COMBI Energy balance model. Power sector model to determine mix of power plant and cogeneration plant technologies and capacities. Relevant output is net power output. Avoided power output multiplied by specific capital costs per technology.
	Derated reserve capacity rate	COMBI Energy balance model and power sector model. Model to determine peak loads and required reserve capacities based on annual load duration curves.

Source: Own elaboration (data provided by COMBI partners)

COMBI approach

COMBI takes the following steps to deal with methodological uncertainties related to baseline:

1. A detailed bottom-up stock model is used to calculate reference/baseline and efficiency scenarios through extrapolations of past developments and accounting for current policies (reference/baseline) and additional policies (efficiency) scenario.
2. COMBI thus uses a dynamic baseline that incorporates existing EU policies. This implies that substantial energy efficiency improvements are already incorporated into the baseline.
3. Only incremental EEI actions (without cost optimization) are incorporated in the project – for all estimations: energy savings, investment costs and estimated multiple impacts.

These three specific steps ensure that the baseline is dynamic enough to project both reference and efficiency scenario to assume that quantified impacts are incremental.

1.5 COMBI-quantified impacts

Table 3: List of impact end-points and units

Work package	Impact end-point	Units	Monetization possible	Interactions with other MIs	Overlaps with other impacts and solutions
WP3	Human health	DALY	Yes	-	Health effects due to outdoor pollution overlaps with productivity due to productivity quantification methodology. Thus, to avoid the overlap section productivity impact is further disaggregated to outdoor sources and indoor sources which clarifies the extent of overlap and accordingly productivity is adjusted before incorporating into CBA.
	Eco-systems: acidification	% change in area affected by excess acidification	not within COMBI	-	No overlaps with other impacts
	Eco-systems: eutrophication	% change in area affected by eutrophication	not within COMBI	-	No overlaps with other impacts
	Air pollution: Emissions (mid-points)	In tons	No	Productivity-specifically with Active days	Percentage of active days loss due to outdoor exposure is can be calculated and hence that percentage can be deducted from active days.
WP4	Material Footprint (sum abiotic & biotic & unused)	In tons	Partially	-	Material footprint is a summation of abiotic, biotic and unused materials hence incorporation of material footprint automatically includes abiotic, biotic and unused materials. However, since material footprint is partially monetized due to methodological complexities, the monetary value is underestimated for resources. Full overlap with investment costs (material inputs part of production costs)
	Life-Cycle wide fossil fuel consumption (additional to direct combustion)	In tons	Yes	-	Overlap with energy cost savings
	Metal Ores	In tons	Yes (partially)	-	See above: full overlap with investment
	Minerals	In tons	Not within COMBI	-	See above: full overlap with investment
	Biotic raw materials	In tons	Not within COMBI	-	See above: full overlap with investment
	Unused extraction	In tons	No	-	–
	Direct carbon emissions	Mt CO2eq (GWP 100a)	Yes	Interacts with carbon footprint	Double counting does not occur as carbon footprint is not monetised.

	Carbon Footprint (GWP, lifecycle missions incl. direct emissions)	Mt CO2eq (GWP 100a)	No	Interacts with direct carbon emission	Double counting does not occur as carbon footprint is not monetised
WP5	Excess winter mortality attributable to inadequate housing	Number of deaths avoided due to improved building ventilation	Yes	-	No overlaps with other impacts
	Excess winter morbidity attributable to inadequate housing	DALY	Yes	-	No overlaps with other impacts
	Indoor dampness/asthma	DALY	Yes	-	No double counting between dampness related asthma and active days loss from asthma as dampness related asthma only considers dampness from inadequate heating. On the other hand, active days from asthma does not consider the any temperature related health effects.
	Active days (sick days ,DALY[1] and avoiding road congestion) due to asthma, cold and flu, Cardiovascular disease, cancer, COPD	Number of days gained from indoor exposure-related diseases and time saved by avoiding traffic congestion	Yes	-	As mentioned above, as active days calculations do not incorporate any heating-related effects whereas indoor dampness/asthma methodology is based on heating condition.
	Workforce Performance	Labour input per hour	Yes		No overlaps with other impacts
WP6	Temporary (business-cycle) GDP effects	€	Yes		Overlaps with energy costs, investments and potentially all multiple impacts
	Temporary (business-cycle) employment/GDP effects	Number of job years	No		If monetized, full overlap with GDP
	Temporary (business-cycle) public budget effects	€	Yes		No overlaps with other impacts
	Fossil fuel price effects*	€/MWh, % change	Yes	-	The price of fossil fuel is adjusted to maintain consistency with energy import end-point. However, since they are not aggregated, there would be no double counting.
	ETS price effect*	€/tCO2	Yes		No overlaps with other impacts
	Terms of Trade effect*	TOT index change	No		No overlaps with other impacts
WP7	Energy intensity	ktoe/1000€	No		
	Import dependency	Herfindahl-Hirschman index HHI	No	-	Only consider energy cost saving that captures import dependency

1Sick days is calculated based on absenteeism and presenteeism due to asthma, cold and flu and cardiovascular disease and DALY is calculated due to asthma, cold and flu, cardiovascular disease, Chronic obstructive pulmonary disease (COPD)and cancer

	Aggregated energy security index	No		No overlaps
	Avoided electric power output & investment costs	TWh	Yes	No overlaps
	Derated reserve capacity rate	Share (%)	No	No overlaps

* not included in the COMBI online tool, because quantified only at total EU level. Results available from D6.4 report.

1.6 Impact synthesis

The target of COMBI is to bring all quantified multiple impacts together in one centralised database and to perform a cost-benefit analysis (CBA) that includes as many multiple impacts as possible. The first pre-condition for multiple impacts to enter any CBA is that they can be brought to a common unit, i.e. that they can be monetized. The second precondition is to include only impacts, where any danger of double-counting can be definitely ruled out. To this end, COMBI developed a systematic way of looking at impacts leading to the exclusion of many quantified and monetized impacts from CBA although they would at least *partially* be additive – as a consequence, COMBI cost-benefit analyses are on the conservative side.

The mathematical aggregation of different monetized impacts is a simple aggregation.[2] The difficult question was to determine, which impacts can safely be included to the CBA avoiding double-counting. The approach is outlined in detail in the dedicated D2.4 Synthesis report. This section includes an outline of the COMBI quantification and synthesis methodology in 7 steps:

1. Identify the impacts and root causes of the impacts explicitly
2. Identify the causal effects of an impact i.e. whether the impact results in another impact
3. Choose significant end-points
4. Quantify the incremental impacts in physical units
5. Monetize the physical value
6. Aggregation of impacts
7. Incorporate the monetised value in a decision-making analysis such cost-benefit analysis (CBA), marginal abatement cost curve (MCA).

In order to identify the interactions among the impacts and also in order to understand the causal effects of impacts in a detailed manner, COMBI uses the impact pathway approach for the first 3 steps.

The impact pathway approach (first proposed in the ExternE project) decomposes the chain of effects linking a root cause or causes starting from the implementation of an energy efficiency improvement (EEI) action until all the way to the impact receptor or welfare endpoint, i.e. the impact that directly leads towards utility. The aim of this approach is to better identify and characterize the interaction among impacts. An impact pathway map enables the representation of the mul-

2In principle, there might be interactions and/or scale effects where the size of one impact depends on the size/level of another. However, such effects would require either a joint model allowing for these cross-impacts or iterative model runs. Both was not possible in COMBI due to time constraints.

tiple impacts in a way that facilitates a more consistent and comprehensive accounting of impacts and also, catalyzes their integration in a way that minimizes double counting and the under- and overestimation problems.

Figure 1 shows the complex pathways of impacts quantified in COMBI. All possible interaction effects were discussed in detail and either ruled out in quantification methodologies or accounted for. Where they could not be entirely excluded, the decision was not to allow the respective impacts to enter CBA. The D2.4 report describes the proceeding in detail. The below Table 4 lists impact end-points with their possible inclusion (✓) or exclusion (✗) to the COMBI CBA and gives a brief reasoning for their in-/exclusion.

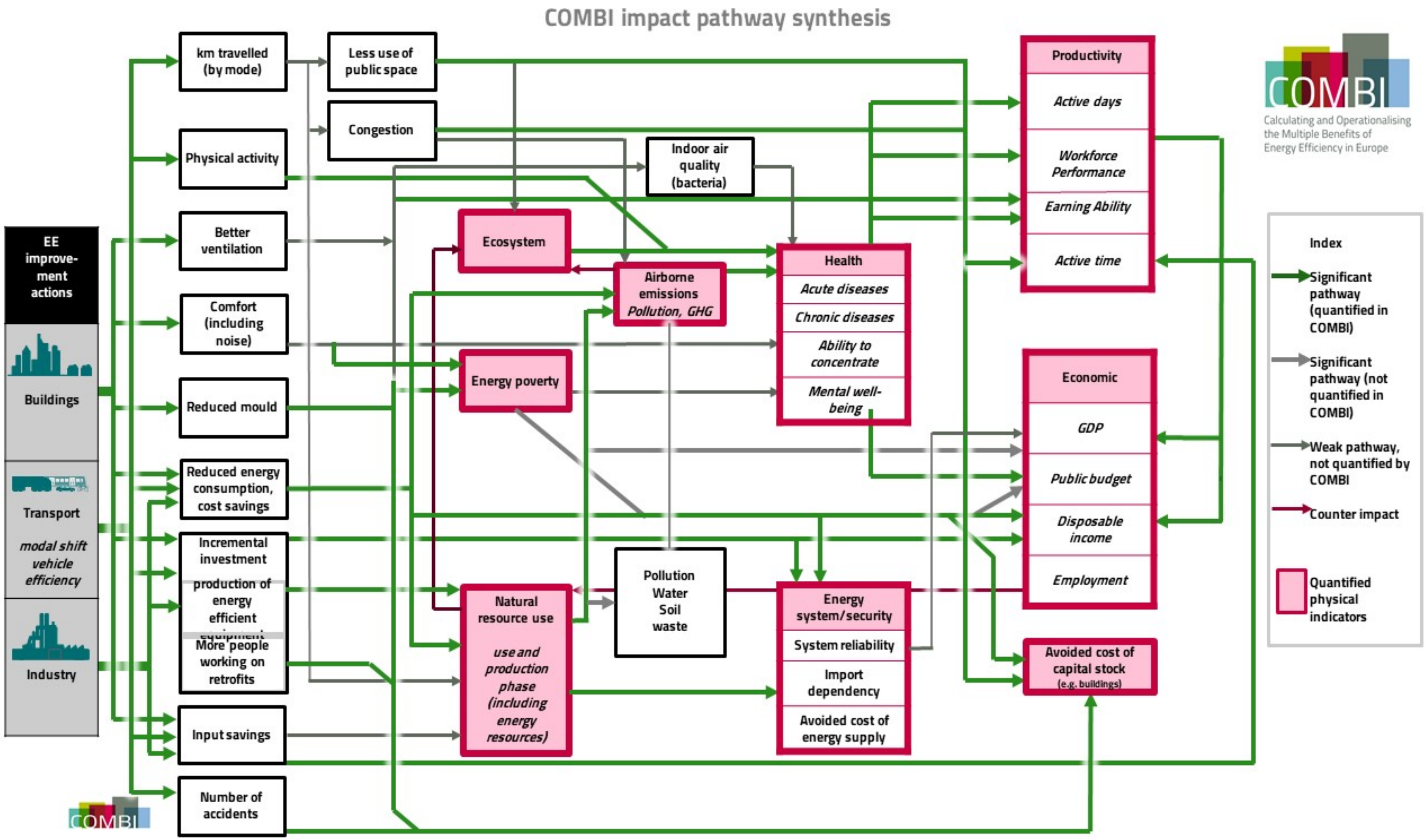


Figure 1: Impact pathway map incorporating all the impact category

Source: Own elaboration

Table 4: Inclusion of impacts to COMBI CBA

Work package	Impact end-point	Inclusion/ exclusion to CBA	Reasoning
WP3	Human health	✓	Existing overlaps with productivity accounted in WP5
	Eco-systems: acidification	✗	not monetized
	Eco-systems: eutrophication	✗	not monetized
	Air pollution: Emissions(mid-points)	✗	not monetized
WP4	Material Footprint (sum abiotic & biotic & unused)	✗	Full overlap with investment costs (material inputs part of production costs)
	Life-Cycle wide fossil fuel consumption (additional to direct combustion)	✗	Full overlap with investment costs (material inputs part of production costs)
	Metal Ores	✗	Full overlap with investment costs (material inputs part of production costs)
	Minerals	✗	not monetized
	Biotic raw materials	✗	not monetized
	Unused extraction	✗	not monetized
	Direct carbon emissions	✓	No overlaps with other impacts
	Carbon Footprint (GWP, lifecycle missions incl. direct emissions)	✗	not monetized
WP5	Excess winter mortality attributable to inadequate housing	✓	No overlaps with other impacts
	Excess winter morbidity attributable to inadequate housing	✓	No overlaps with other impacts
	Indoor dampness/asthma	✓	Overlaps with outdoor air pollution accounted for in dedicated quantification efforts
	Active days (sick days ,DALY and avoiding road congestion) due to asthma, cold and flu, Cardiovascular disease, cancer, COPD	✓	Overlaps with outdoor air pollution accounted for in dedicated quantification efforts
	Workforce Performance	✓	No overlaps with other impacts
WP6	Temporary (business-cycle) GDP effects	✗	Overlaps with energy costs, investments and potentially all multiple impacts
	Temporary (business-cycle) employment/GDP effects	✗	not monetized
	Temporary (business-cycle) public budget effects	✗	Rather analysable as separate evaluation perspective, not aggregable
	Fossil fuel price effects*	✗	quantified only at EU level
	ETS price effect*	✗	quantified only at EU level
	Terms of Trade effect*	✗	quantified only at EU level
WP7	Energy intensity	✗	not monetized
	Import dependency	✗	not monetized
	Aggregated energy security index	✗	not monetized
	Avoided electric power output & investment costs	✓	no overlaps
	Derated reserve capacity rate	✗	not monetized

From the above table follows, that only a very limited list of COMBI-monetized actions could be allowed to enter Cost-Benefit Analysis for which double-counting could be ruled out. The COMBI CBA can thus be regarded as a conservative estimation of multiple impacts as many impacts that do certainly exist could not be monetized (or even physically quantified). See more on this issue in the D2.4 report.

1.7 Cost-Benefit Analysis

The COMBI online tool allows for a variety of Cost-Benefit indicators:

- Life-Time net present value
- Annualised net present value
- Levelised cost of energy saved and of GHG emissions saved
- Cost-Benefit and Benefit-Cost ratios
- Marginal cost curves

More details on CBA indicators and the mathematical formulae for the calculation of indicators are explained in detail in the D8.1 Tool documentation.

1.8 Sensitivity analysis

COMBI results are generally point estimates resulting from complex modelling exercises. By nature, such models include numerous assumptions, the most of which are laid down in the respective quantification reports of the Work Packages 2–7 (D3.4–D7.4). Due to the number and nature of models, it is impossible to construct confidence intervals, because these would have to be based on confidence intervals for any intervening variable from the implementation of an EEI action until the finally quantified result – for all modelling years. This would results in meaningless scenarios.

Therefore, COMBI followed the path usually taken in modelling: applying most plausible values, documenting them for transparency and where possible and necessary, also quantifying scenarios for sensitivity analysis. Examples for this proceeding are sensitivities quantified for the impact of whether policies are targeted towards energy poor households on the energy poverty-related health impacts; or the size of macroeconomic impacts that depend on the expansion capacity of a given EU economy in the year 2030.

In addition to these sensitivities studied in the respective D3.4–D7.4 quantification reports, COMBI also included two options for users of the online tool to directly test CBA results for sensitivity on two variables:

- Energy price scenarios (deviating ±10% from the COMBI forecast)
- Discount rates directly entering the CBA calculation formula (COMBI standard rate at 3%, option for user to apply different rates of 0–10%)

1.9 Caveats and open issues of COMBI quantifications

As the preceding section has discussed, the COMBI results depend, as any forward-looking scenario analysis, on many assumptions. These assumptions have to be kept in mind when communicating and working with the project results. Additionally, other caveats and open issues should be considered while working with our results. These caveats can be subsumed into three broad categories:

- Missing data and data limitations
- Model limitations
- Linking models and modelling interdependencies

The following Table 5 summarises the main points brought up in the discussion of the different work package results into these three categories.

Table 5: Main COMBI caveats

Category	Items
Missing data and data limitations	• PRIMES data was not available in the detail needed for some modelling approaches (WPs 4, 5, 7) • A quantification of non-health social impacts (e.g. comfort, energy poverty) has not been possible, because WP2 input data was not adequate and data necessary for the quantification not available (WP 5) • Data on product specifications from input data was not available for most actions, therefore resource consumption in the production phase could not be estimated for most actions (WP 4) • No reliable forecast for the output gap in 2030 (and therefore the degree of realisation for GDP and employment effects) was possible (WP 6)
Model limitations	• GAINS does not quantify morbidity, only mortality and years of life lost (WP 3) • GAINS produces a conservative estimate of economic losses due to lost lives (WP 3) • GAINS models the effects of air pollution on a regional or national scale, though some effects may be concentrated locally (WP 3) • Energy and resource flows within Europe and to the rest of the world (import and export) had to be neglected in resource calculations (WP 4) • Usual limitations of macro-economic models (Input-Output models, CGE models) • The public budget effect is only estimated based on budgetary semi-elasticities, which does not include certain other impacts relevant for public budgets (e.g. changes in energy tax revenue) (WP 6) • Energy import, power system and reliability indicators could only be based on aggregated energy balances (WP 7) • Energy security indicators are based on value-laden assessments of political risks and are highly sensitive to a variation of assumptions (WP 7)
Linking models and modelling interdependencies	• Sizes and types of power plants and grids are fixed between COMBI scenarios → lowered energy demand would induce the electrical power system to be scaled to demand and thereby also affect resource consumption (WP 4) • An iterative feedback between the macroeconomic model (WP 6) and energy security calculations (WP 7) could not be realized due to constraints but seems advisable • Several other feedback loops or model links between COMBI impacts would be advisable but could not be done (e.g. energy prices→ energy costs; other impacts → economy; other impacts → public budget) • Many impacts potentially overlap and were thus excluded from CBA. To be able to include them, two ways could be taken: a) study all interconnections in greater detail and model interdependencies or b) fully integrate models

These categories and their items also constitute hints for future research needs. COMBI has made the first step to integrate the multiple impacts of energy efficiency into cost-benefit analyses. Future research efforts can build on these results and improve them by addressing the caveats and open issues named in Table 5.

2 COMBI quantification results

COMBI quantified all impacts by EU28 member state and by each of the 21 EEI actions, i.e. a 28x21 matrix. The main input data used for impact quantifications includes additional annual energy savings (in 2030), according energy cost savings and additional (total cumulated until 2030 and annualised) investment costs. Graphs below give an overview on this data, respective tables are included in the annex (Table 7, Table 8 for input data, Table 9 for impact quantifications). Full details of data can be retrieved from https://combi-project.eu/charts/

In the tool, mouse-over tooltips additionally give detailed values and a data export function allows downloading all data tables.

D8.1 Detailed manual on how to use the tool and documentation of technical tool infrastructure is available from the download section of the website and directly in the tool

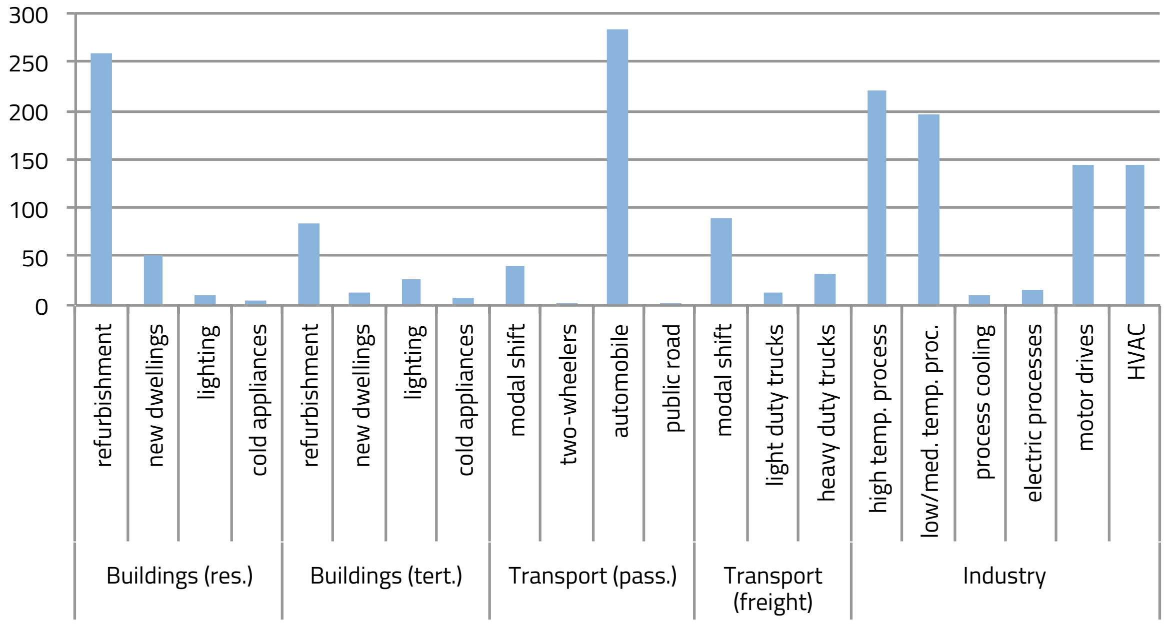
Tool https://combi-project.eu/tool/

2.1 Input data: additional investment, energy and energy cost savings

The implementation of all 21 EEI actions at the level of ambition assumed for the COMBI EE-scenario would lead to additional annual energy savings in 2030 as illustrated in Figure 2 for the respective EEI actions. They total 1647 TWh/year or 142 Mtoe/year in 2030.

Important note: for two groups of actions, investment costs could not be sufficiently well quantified and they are thus also excluded from Cost-Benefit analysis. This concerns on one side passenger and transport modal shift. For these actions, (incremental changes in) investment costs into rolling stock were quantified (and are included in the tables in the annex), but additional infrastructure investment costs (into e.g. road and rail infrastructure) could not. A holistic societal CBA is thus not possible. On the other side, investment costs for transport actions base on available data before 2015. Since then, significant technological advances and cost reductions have taken place (especially for freight transport), so we believe this data does not reflect 2018 (let alone 2030) reality. We thus also exclude freight transport from CBA. Tables in the annex however reflect the data status we had available.

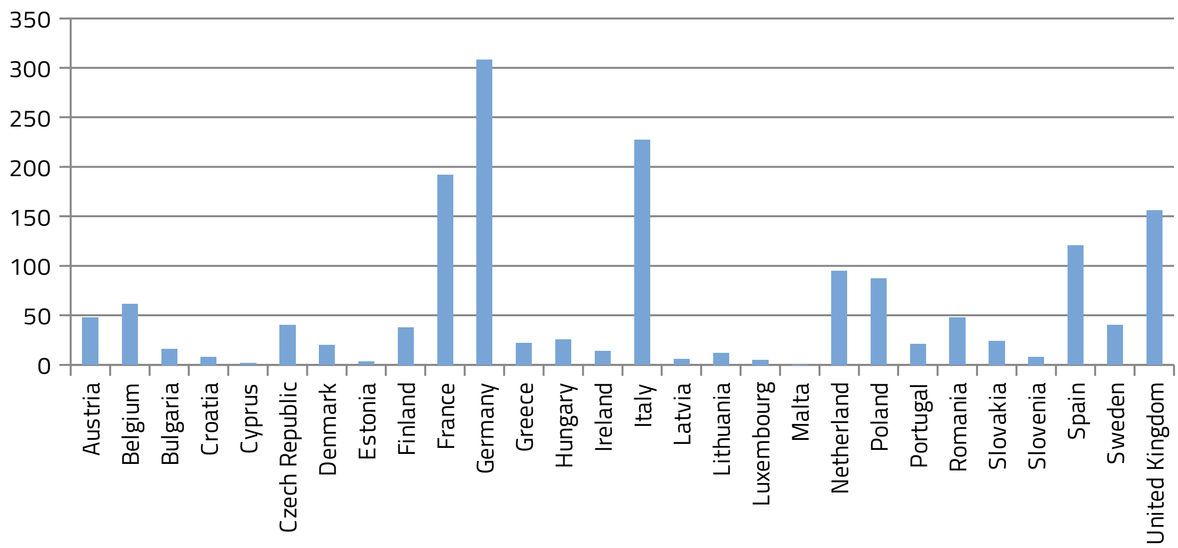
Figure 2: Additional energy savings (all fuels, total EU28) in TWh/year in 2030 by EEI action



View graph in COMBI tool

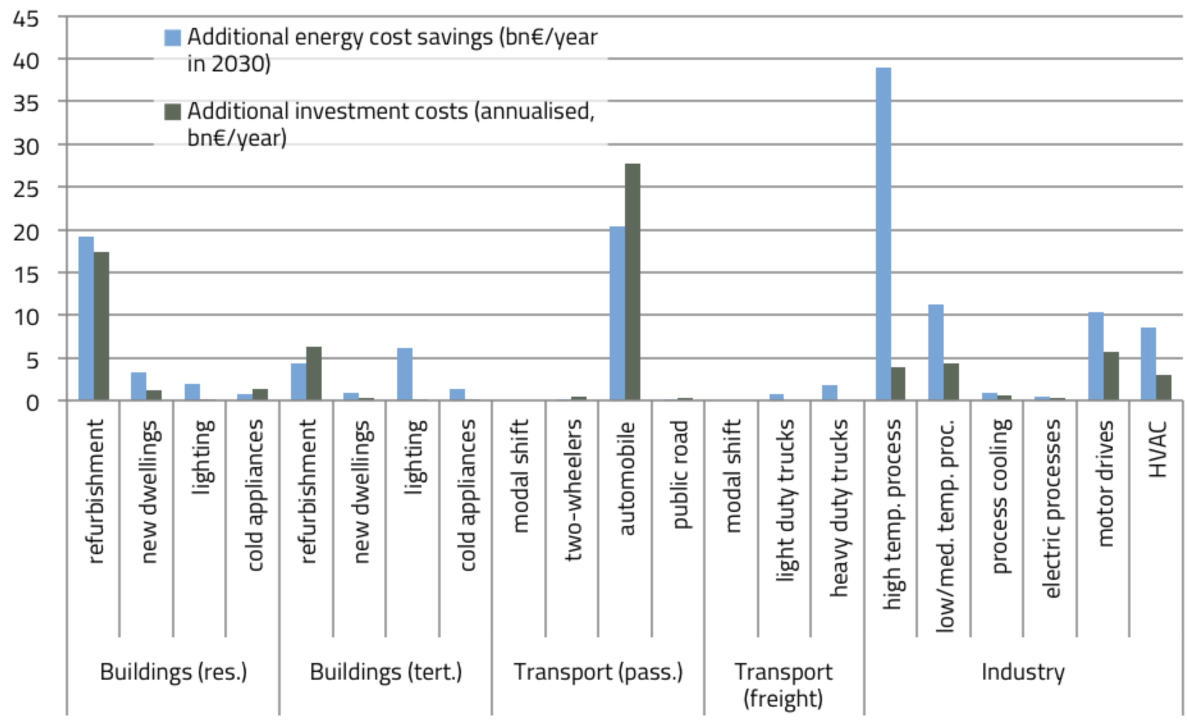
The total energy savings for all 21 EEI actions by EU28 member state are shown in Figure 3.

Figure 3: Additional energy savings (all fuels and EEI actions) in TWh/year by EU28 member state



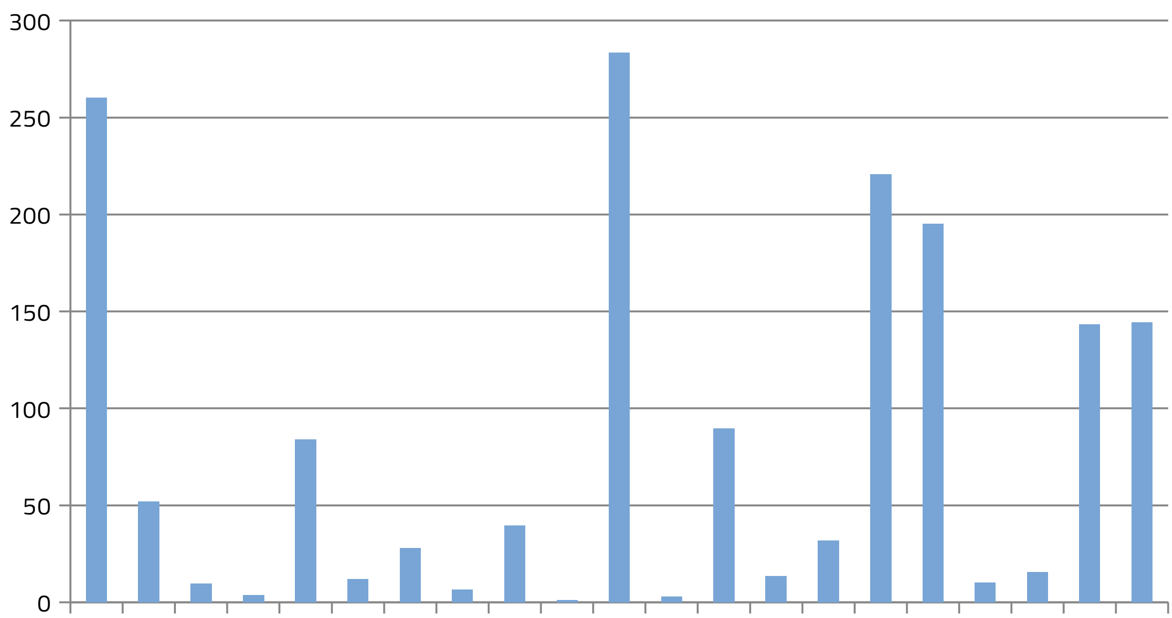
View graph in COMBI tool

Figure 4: Additional energy cost savings and (annualised) incremental investment costs in bn€/year by EEI action (societal perspective)



View graph in COMBI tool (CBA graph)

Figure 5: Additional energy cost savings and (annualised) incremental investment costs in bn€/year by EU28 member state (societal perspective)



View graph in COMBI tool (CBA graph)

These figures show the energy impacts – energy savings and energy cost savings – of additional energy efficiency actions for the COMBI efficiency scenario. Thus the energy impact is already considerable. Results from COMBI quantifications show that further non-energy impacts are likely to add significant benefits, including economic benefits. These “multiple impacts” are outlined in the following chapter.

Multiple impacts: results from COMBI quantifications

For an overview on the list of quantified impacts see Table 3 above. COMBI quantified all impacts by EU28 member state and 21 EEI actions. In total impacts cover energy savings, investment costs plus 30 additional impacts, for 17 of which it was possible to also monetise them. However, there are double-counting issues for a number of impacts, therefore only 11 are allowed to enter cost-benefit analysis. For more details on the Cost-Benefit Analysis see chapter 3.2 and especially the D2.4 synthesis methodology and D8.1 online tool report.

Due to the resulting amount of data and possible graphing combinations, it is not sensible to reproduce all results in this 2.7 report. All impacts quantified by COMBI are available from the COMBI online tool (https://combi-project.eu/tool/)

- by country
- by EEI action
- physical, monetary (where possible), in CBA (where eligible)

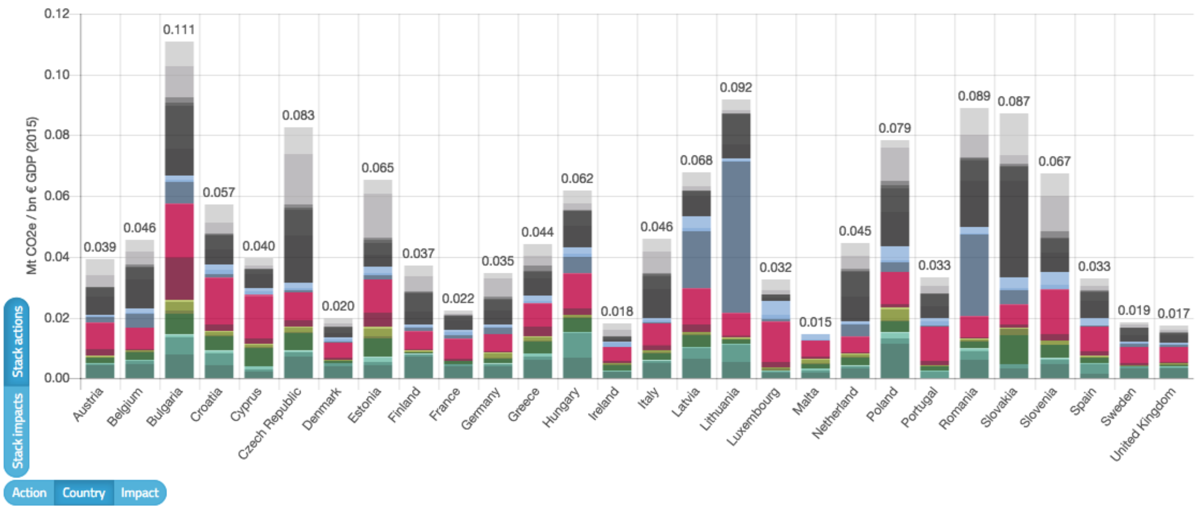
The following section presents snapshots of the data and graphs available from the tool.

2.2 Climate impacts: Mitigation of 360–500 Mt CO2eq

COMBI quantifies two impacts on the climate: savings of direct GHG emissions from combustion in the use phase of technologies, and savings in the carbon footprint including upstream emissions from the provision chain of energy resources consumed in the use phase. For transport and lighting actions, also emissions from the production phase are included.

Total avoided direct emissions in the EU by COMBI EEI actions sum up to 362 Mt annually. Including indirect upstream emissions, the avoided EU carbon footprint amounts to 509 Mt/a.

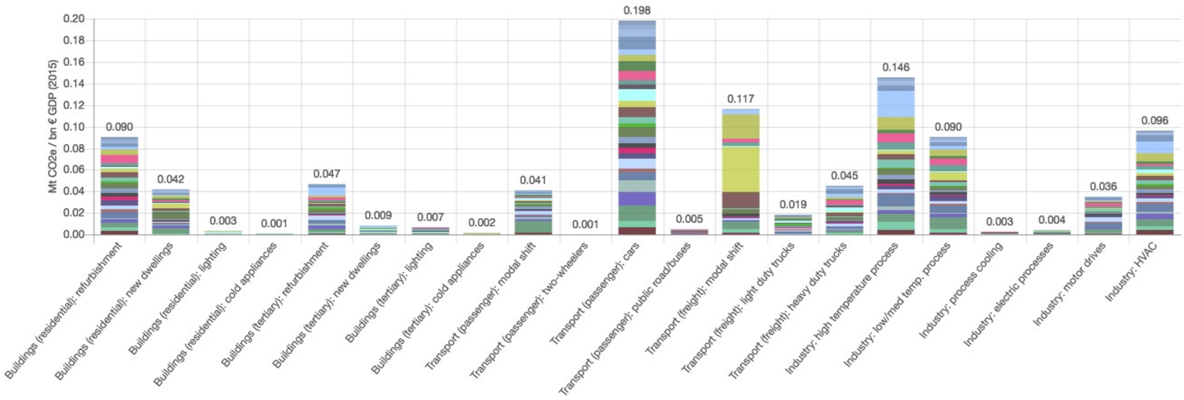
Figure 6: Avoided carbon footprint (per GDP) including direct and indirect/upstream emissions of fossil fuel combustion in Mt CO2eq in EU28



View graph in COMBI tool

- especially high impacts per GDP in Eastern European countries
- high impacts per 2015 GDP from transport and industry sector (View graph in COMBI tool)

Figure 7: Avoided direct GHG emissions (per GDP) from fuel combustion in Mt CO2eq in EU28



View graph in COMBI tool

- high impacts from transport and industry sector
- especially in Eastern European countries (view graph in COMBI tool)

2.3 Macro-economic impacts: up to 1% of GDP, 2.3mn job-years and lower fossil fuel prices

COMBI quantifications are annual impacts in the year 2030, that result from energy efficiency actions throughout Europe leading to energy savings of about 8% relative to a reference scenario.

Macro-economic impacts are quantified using two modelling approaches: input-output modelling for short-term (business cycle) effects and CGE modelling for long-term/structural effects. As also seen in other modelling (e.g. EU-COM impact assessment of EED), these models give a range of possible outcomes.

In the short run, the positive macro-economic stimulus is substantial; we estimate 0.9 per cent of EU's GDP and a positive effect on the labour market of about 2.3 mn job-years. However, this stimulus will only materialise in countries with idle resources in 2030 that can support further growth (negative output gap, situation of economic downturn). In 2018, about half of the EU28 Member States are expected to have a negative output gap.

From applying budgetary semi-elasticities, also effects on public budget are estimated. The total effect amounts to up to 85 bn€ annually.

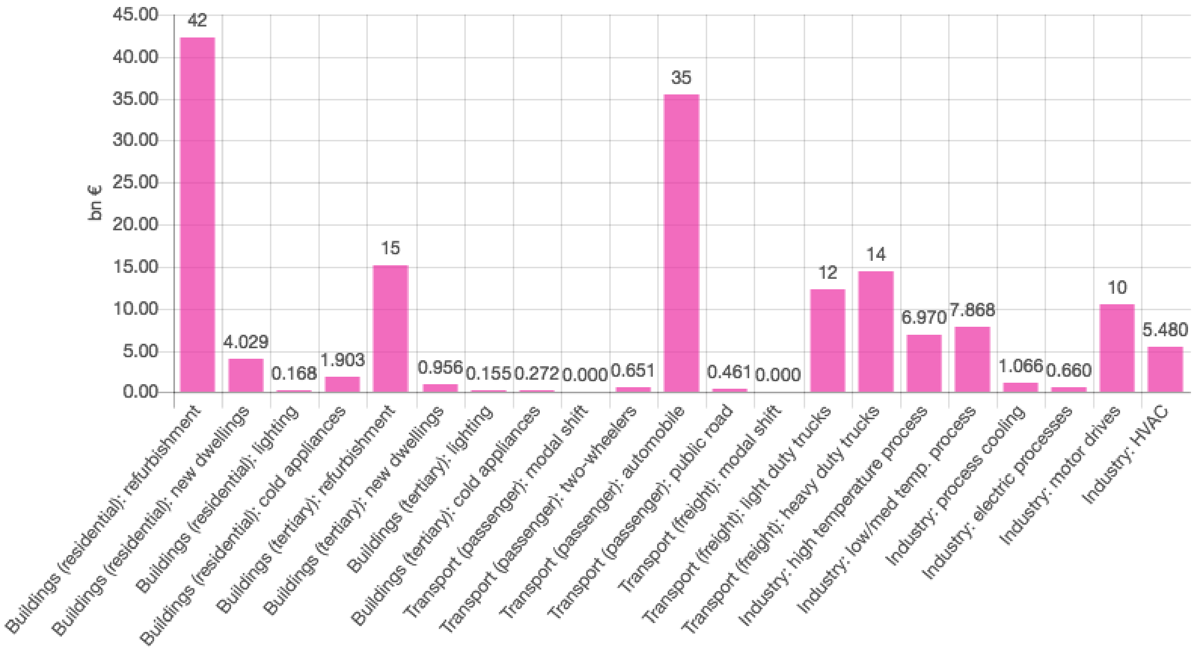
In the long run, CGE (Computable General Equilibrium) modelling does not show significant impacts on employment and even slightly negative impacts on GDP. However, energy efficiency will still lead to a reduction in CO2 emissions and significantly lowered carbon allowance and fossil fuel prices, which, given all EU countries are net fossil fuel importers will also improve their terms of trade.

This section presents only short-run impacts, long-run impacts are included in the D6.4 quantification report: D6.4 quantification report

GDP and employment impacts ('physical' impacts)

For (short-run) macro-economic impacts, different impact pathways and impacts have been analysed in COMBI: change in aggregate demand/GDP, public budget and employment effects. Accordingly, impacts are quantified in different units: employment in 1000-person-years and GDP as well as public budget in bn€. These specific impacts can be accessed in the expert mode of the tool.

Figure 8: Short-term increase in GDP for total EU (bn€/year) by EEI action[3]

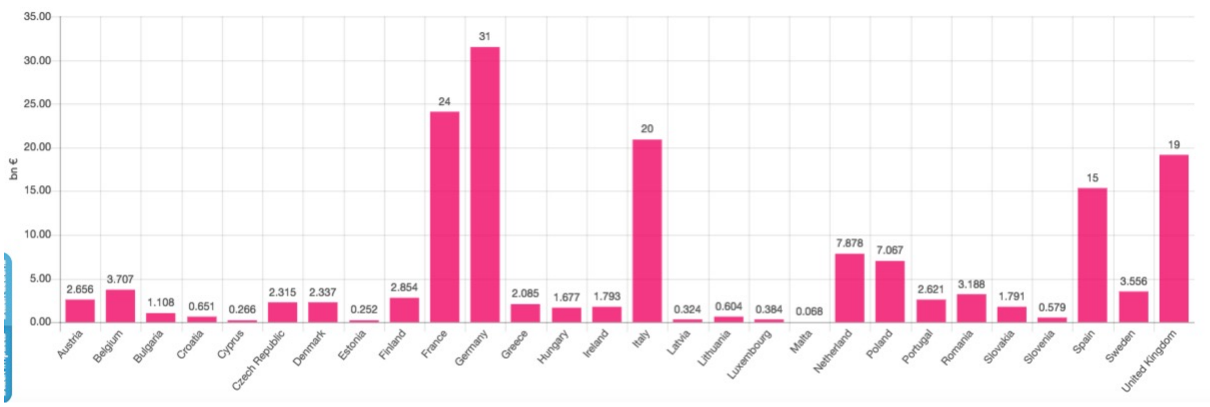


[View graph in COMBI tool](#)

The short-term increase in GDP for the EU28 (modelled through IO-models) is created mostly due to the actions aiming at buildings and the transport sector, as Figure 8 shows. Impacts are highest for actions with high investment values that then also hit through to other sectors.

The GDP effects vary between member states. Figure 9 highlights which countries would see which short-term increase in GDP. Not surprisingly, large countries show large impacts. Therefore, any impact quantifications can also be normalised to make more meaningful comparisons.

Figure 9: Short-term increase in GDP (bn€/year) by EU28 member state[4]

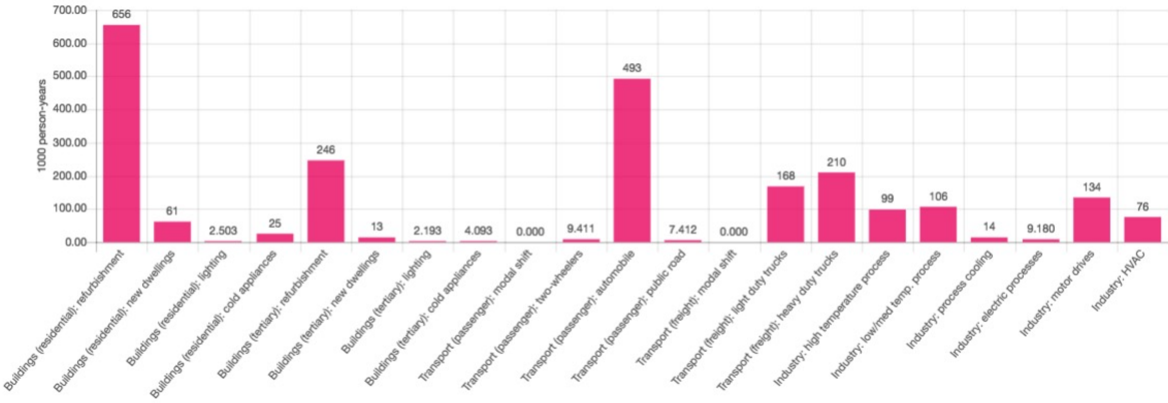


3Note: based on the assumption of an existing output gap in 2030.
4Note: based on the assumption of an existing output gap in 2030.

View graph in COMBI tool

View graph in COMBI tool, normalised by 2015 GDP (i.e. in % points)

Figure 10: Direct (short-term) employment effect in 1000 person-years[5] by EEI action

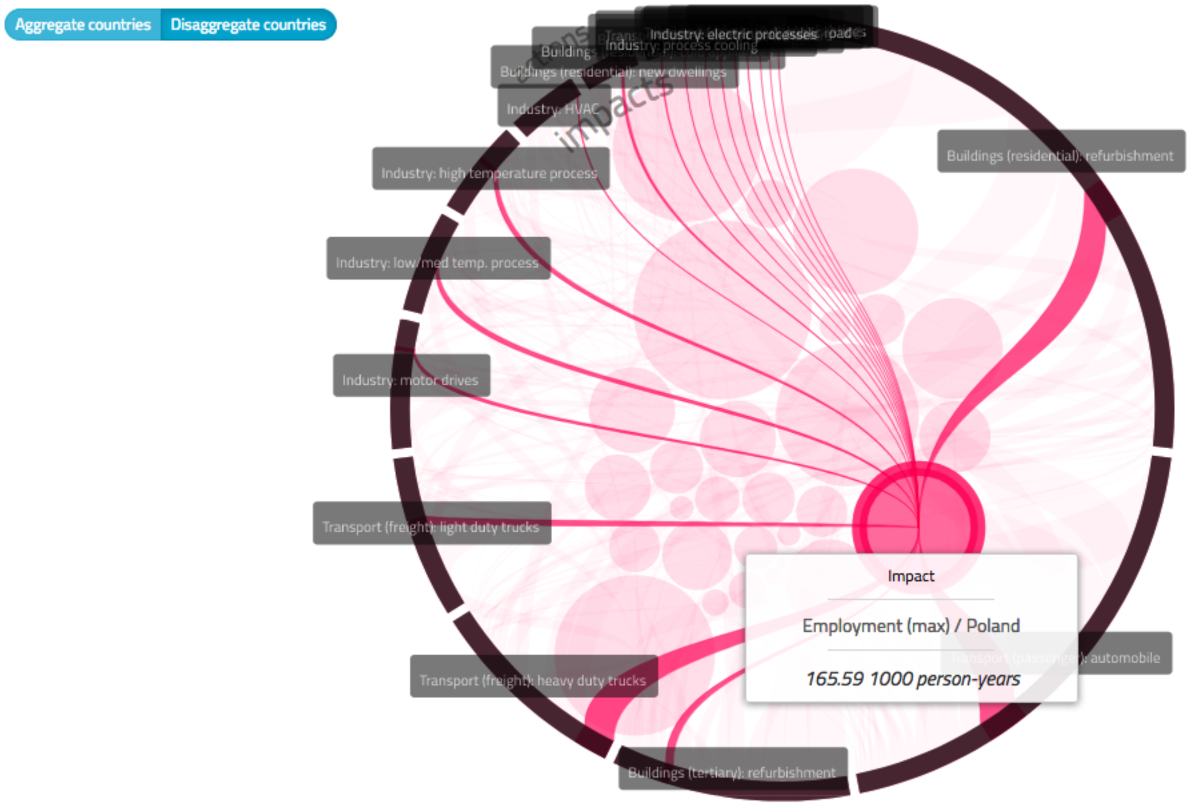


View graph in COMBI tool

Figure 10 shows that the largest number of jobs may be created from EEI actions with high investment values and implemented in labour-intensive sectors: the buildings – both residential and tertiary – and the transport sector. In total, 2,343,000 person-years of employment could be created. For distribution between actions and countries see Figure 11 (can only be meaningfully viewed online with mouse-overs).

5Note: based on the assumption of an existing output gap in 2030.

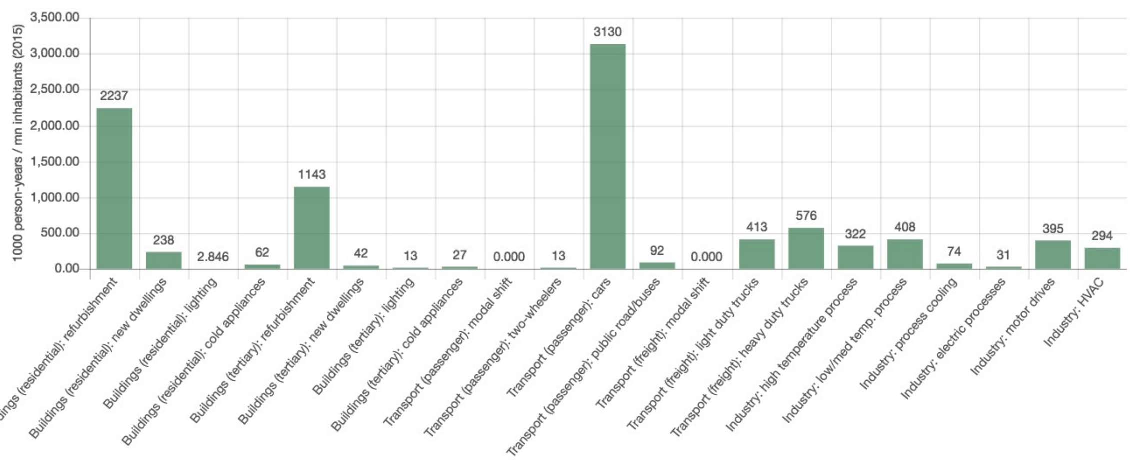
Figure 11: Halo graph of direct (short-term) employment effect[6] in 1000 person-years for all EEI actions (ring) and EU28 member states (bubbles)



[View graph in COMBI tool – online version permits mouse-over information]()

- Employment effects: In total, are larger for bigger countries.
- Employment effects: Per GDP and per capita values differ, but are highest for Bulgaria.

Figure 12: Employment effect[7] for Bulgaria resulting from all EEI actions (expert mode)

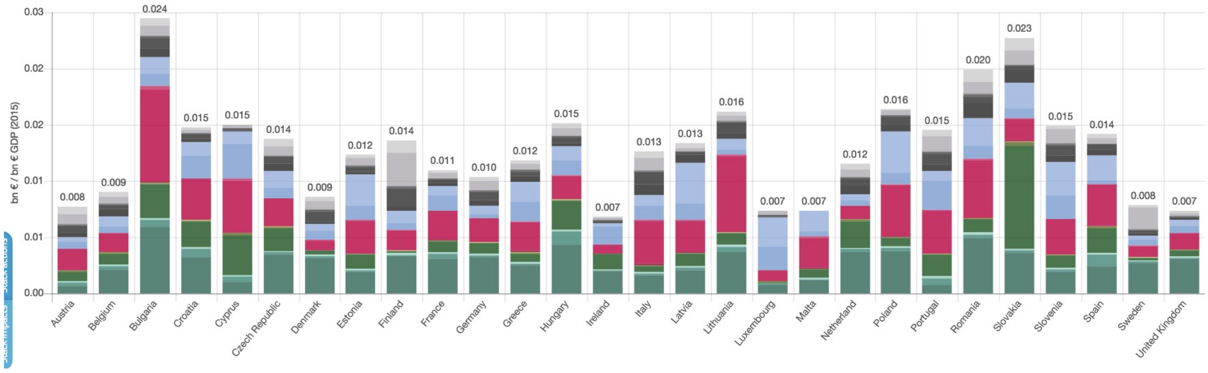


[View graph in COMBI tool]()

6Note: based on the assumption of an existing output gap in 2030.
7Note: based on the assumption of an existing output gap in 2030.

- Bulgaria has the biggest employment effect (per capita) for all EEI actions
- The biggest effects can be found in the buildings and transport sector (as for the whole EU)

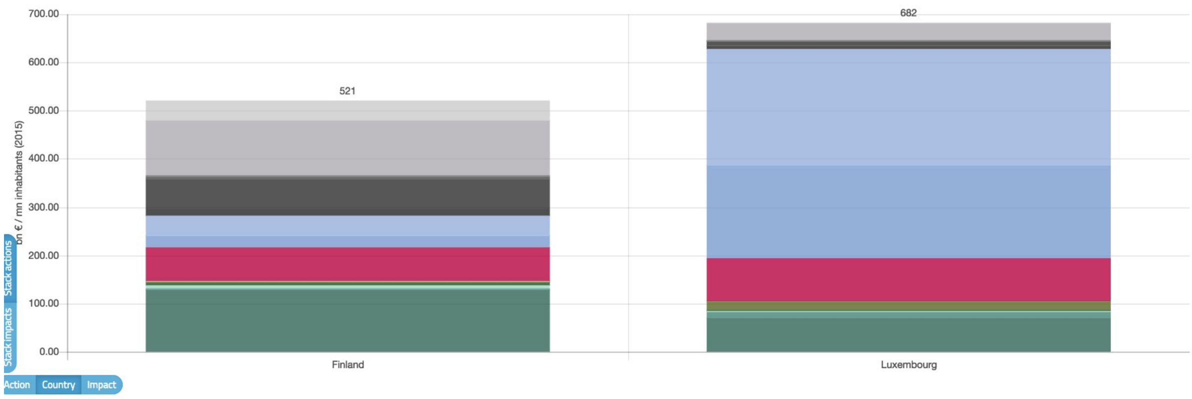
Figure 13: Increase in GDP[8] (per GDP) – expressed as fraction of 1 (%/100)



View graph in COMBI tool

- big countries see higher increases in GDP (in absolute values)
- as percentage of GDP: especially Eastern European Countries see larger increases

Figure 14: Increase in GDP[9] (per capita) for FI and LU



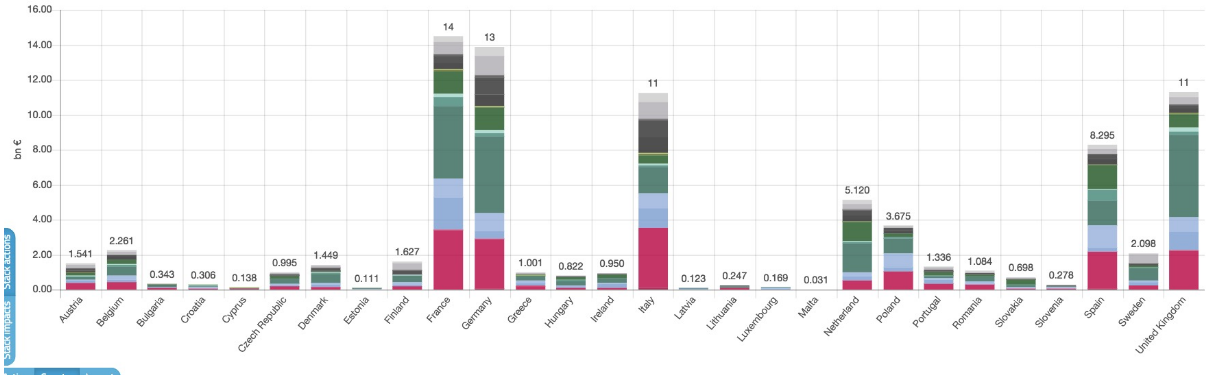
View graph in COMBI tool

- In Finland and Luxembourg, GDP effects are more concentrated on certain sectors than in other countries
- Increase in GDP (per capita) is highest for Luxembourg and Finland due to actions in two different sectors
  - Luxembourg: 522 of 682 bn € / mn inhabitants (2015), especially high from EEI actions in the transport sector
  - Finland: 239 of 521 bn € / mn inhabitants (2015), especially high from EEI actions in the industry sector

8Note: based on the assumption of an existing output gap in 2030.
9Note: based on the assumption of an existing output gap in 2030.

Public budget effects

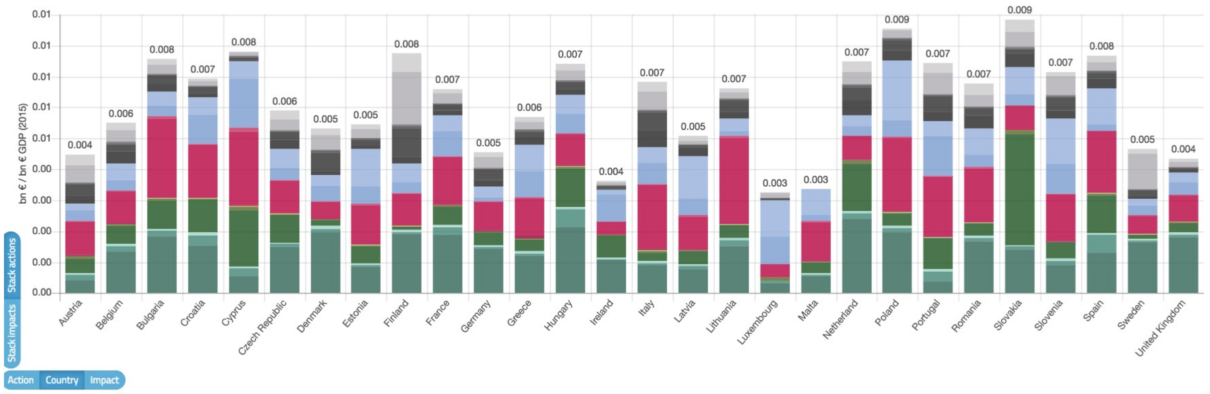
Figure 15: Public budget effect[10] (total)



View graph in COMBI tool

- public budget effects (in absolute terms) not surprisingly are highest in the larger EU countries France, Germany, Italy, Spain and the United Kingdom

Figure 16: Public budget effect[11] (per GDP)



View graph in COMBI tool

- public budget effects expressed per GDP are more evenly distributed among EU28, rather high for EEU countries, and lower for CEU countries
- EEI actions with a marked effect are mainly from the transport and buildings sector (due to higher budgetary semi-elasticities), with some country-specific deviations

10Note: based on the assumption of an existing output gap in 2030.

11Note: based on the assumption of an existing output gap in 2030.

2.4 Air pollution and its impacts: Possibly over 11,000 premature deaths and loss of 230,000 life-years annually avoided

Air pollution is still the single largest environmental threat to human health in Europe. COMBI applied the GAINS model (Greenhouse Gas – Air Pollution Interactions and Synergies model from the IIASA institute) to quantify effects of accelerated energy efficiency improvements on air pollution.

Accelerated EEI actions between 2015 and 2030 would bring these additional benefits in the year 2030:

- Additional 10,805 premature deaths would be avoided due to reduced exposure to particulate matter (PM2.5) in the EU-28
- additional 442 deaths would be avoided due to reduced exposure to ground level ozone.
- Avoided life expectancy loss due to PM2.5 exposure in the year 2030 stands at around 230,000 Years of Life Lost (YOLLs) for the whole of the EU-28.
- Additional 4.4 thousand km2 would de spared from acidification and an additional 13.3 thousand km2 would be spared from eutrophication
- In monetary terms, the value of avoidable mortality may amount to 460 million EUR due to PM2.5 and 46 million EUR due to ground level ozone in the year 2030 for the EU-28.
- The value of avoided life expectancy loss would stand at immense 26 billion EUR in 2030 for the EU-28 – note: as with all impacts, this is only the incremental value, difference between the two scenarios of the year 2030.

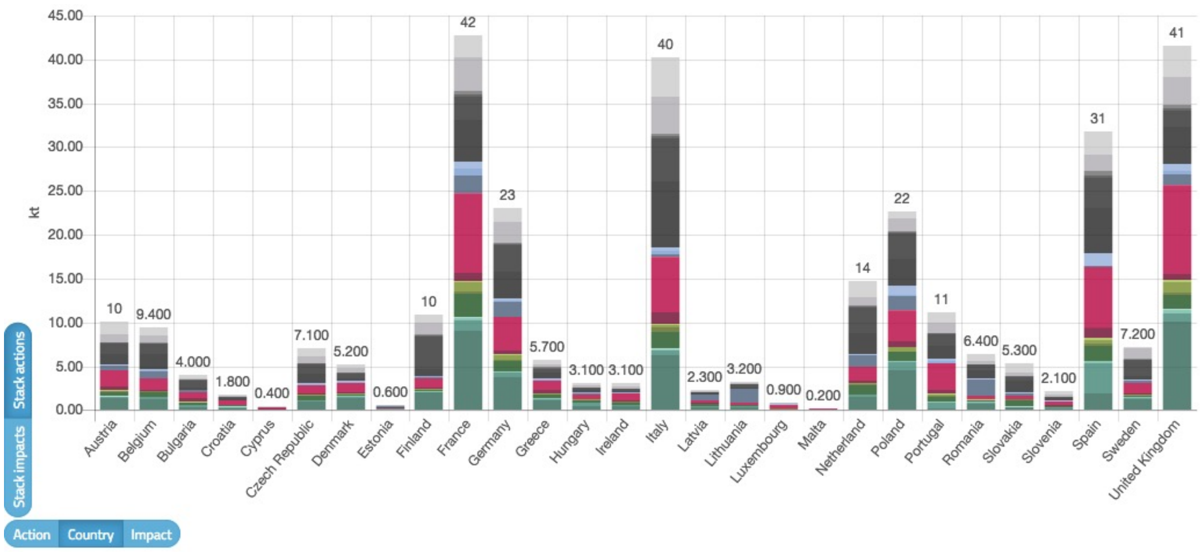
More details and full quantification report

Air pollutants

All air pollutants in COMBI, are measured in kilotonnes (kt). Note: the COMBI quantification was done for total energy savings per country and allocated to EEI actions by weights of energy savings.

Below figures present interesting snapshots, however, the tool offers additional graphs and calculations (e.g. total/per GDP/per capita figures or analyses by countries/actions).

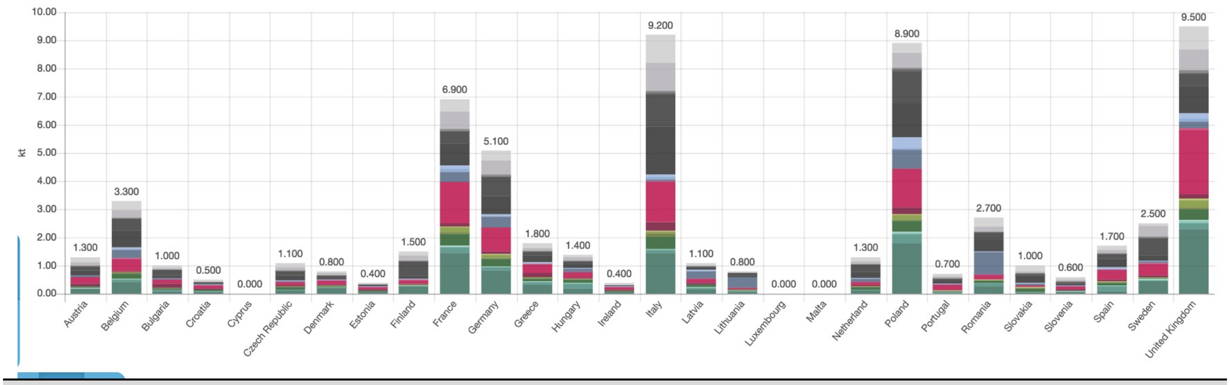
Figure 17: Avoided NOx emissions in EU-28



[View graph in COMBI tool]
[View graph in COMBI tool] **(per GDP)**

Total avoidable nitrogen oxide emissions (NOx) amount to 316kt/a for the EU28 and are especially high for France, Italy, Spain and the UK. Analysing avoidable NOx emissions per GDP, Latvia, Lithuania and Bulgaria stick out with especially high reduction potentials, Germany, Sweden, the UK and Ireland with lowest per-GDP reductions.

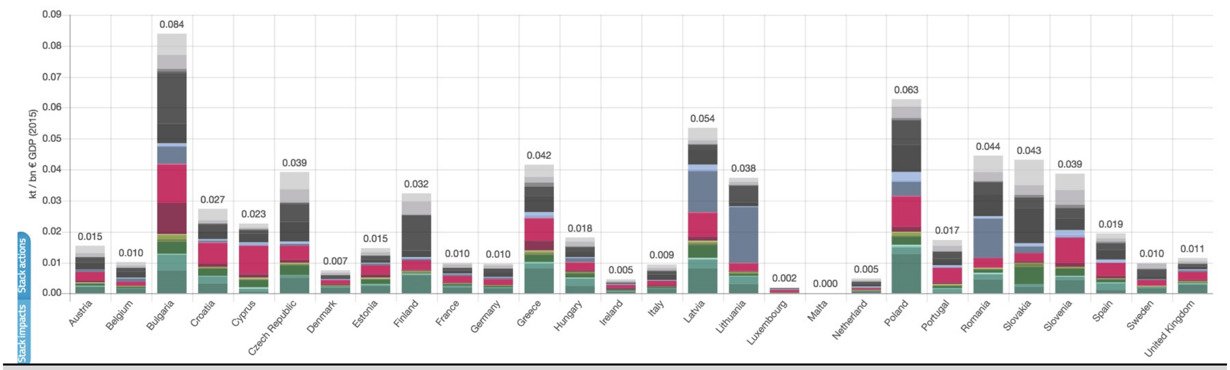
Figure 18: Avoided PM 2.5 emissions in EU-28 in 2030



[View graph in COMBI tool]

- Countries with especially high PM2.5 avoidance are Italy, Poland and the UK, followed by the large countries France and Germany.
- In Italy, 9.200 kt could be avoided, half of the EEI actions are in the industry sector, in other countries, avoided emissions are more evenly distributed between sectors.
- Further EEI actions with major impact on PM2.5 reduction: buildings (residential) refurbishment and passenger transport (cars)
- "In monetary terms, the value of avoided mortality due to *additional* energy efficiency impact actions deployed in 2030 would be 460 million EUR due to PM2.5 [...] for the EU-28" (see report D3.4).

Figure 19: Avoided SO_2 emissions (per GDP) in the EU-28



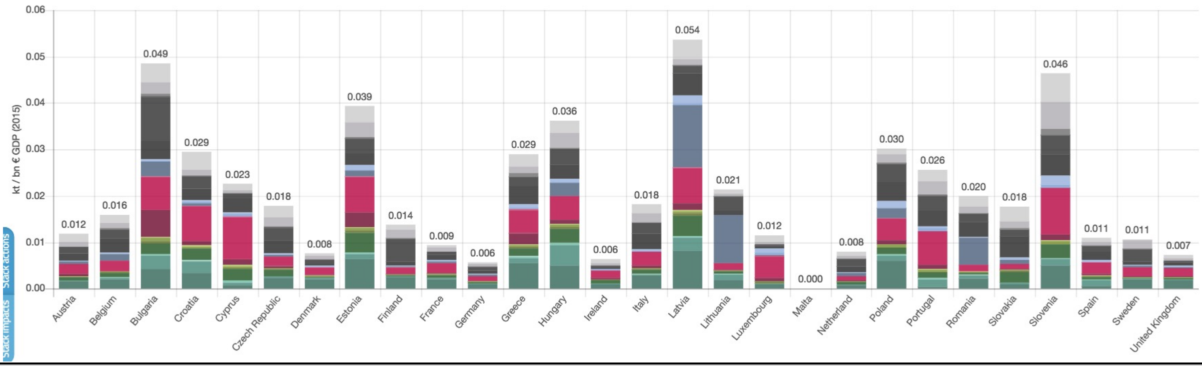
[View graph in COMBI tool]
[View graph in COMBI tool] **(total figures)**

Avoidable sulfur oxide (SO_2) emissions amount to a total of 210kt/a for the EU28, with large countries seeing the highest reductions.

- Generally, per GDP figures of avoided SO_2 emissions are highest in EEU countries

- especially high in Bulgaria due to actions in the transport and industry sector
- especially low in WEU and NEU countries

Figure 20: Avoided VOC emissions (per GDP) in the EU-28



[View graph in COMBI tool]

[View graph in COMBI tool] **(total figures)**

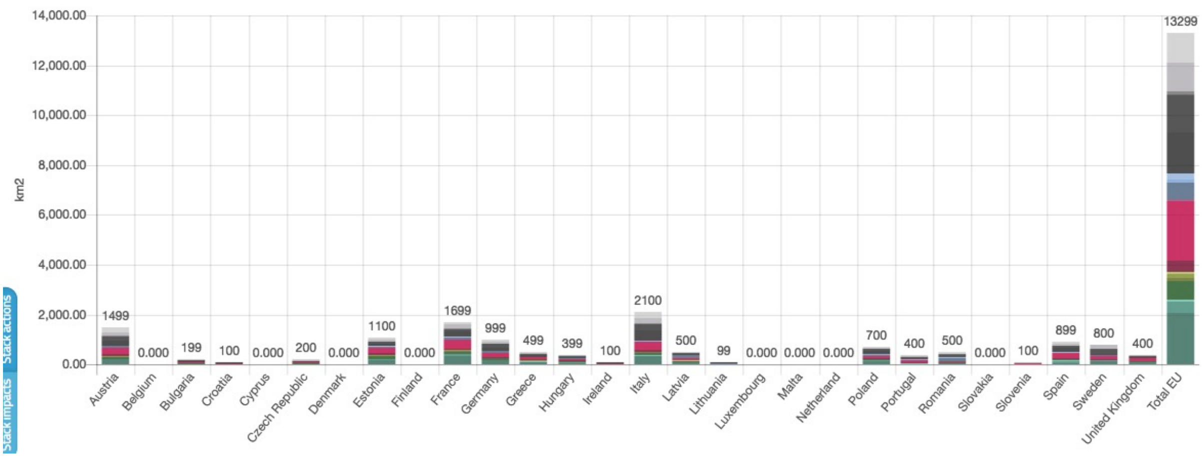
Avoided emissions of volatile organic compounds (VOC) amount to a total of 170kt/a for the EU28, with large countries seeing the highest reductions.

- Per-GDP figures are especially high in Eastern European and Baltic Countries

Effects on ecosystems

„Under COMBI reference scenario in 2030 73.5 thousand km2 remain exposed to excess deposition of sulphur (a reduction of 30% from 2015) and 1024 thousand km2 remain exposed to excess deposition of nitrogen (a reduction of 9% from 2015). Additional 4.4 thousand km2 would be spared from acidification and additional 13.3 thousand km2 (see Figure 21) would be spared from eutrophication under the COMBI efficiency scenario in 2030 – an additional reduction of 4% and 1% respectively." (see report D3.4)

Figure 21: Avoided ecosystem degradation (eutrophication) in km2 in the EU28 in 2030



[View graph in COMBI tool]

Total area of affected ecosystems are highest in the countries with highest NOx impacts. As impacts also contain trans-boundary air pollution, especially for small countries, impacts rather do not come from domestic emissions but from neighbouring countries. This is especially relevant for the high figures in Estonia and Latvia, where affected area that can be spared even amounts to 2.5% and 0.8% of the national territory. Also other smaller countries see high shares of their territory that can be spared: 1.8% in Austria, 0.4% in Portugal – and even large countries like Italy (0.7%), Greece (0.4%).

2.5 Health impacts from air pollution and energy poverty-related building conditions

Different health impact pathways have been analysed in COMBI: health impacts resulting from different air pollutants, from residential and tertiary building indoor conditions, affecting different types of health/sickness and even mortality (see reports D3.4, D5.4 and D5.4a). Accordingly, impacts are quantified in different units: mortality, years of life lost (YOLL) and disability-adjusted life-years (DALY), each according to a specific burden of disease following from certain pressures on health. These specific impacts can be accessed in the expert mode of the tool.

In the standard mode of the tool, all mortality-unit impacts are pre-aggregated as are all life-year related impacts (see Figure 23 and Figure 25).

Health impacts from air pollution
Human health effects arise as a result of short and long-term exposures to various pollutants, and take the form of respiratory, cardiovascular diseases, negative prenatal and developmental outcomes. Although significant air quality improvements have been achieved in the last decades in Europe, air pollution is most probably still the single largest environmental threat to human health, causing acute and chronic diseases.

Annual impacts that can be achieved by COMBI EEI actions in the EU28:

- additional 10 805 premature deaths avoided due to reduced exposure to particulate matter (PM2.5)
- additional 442 deaths would be avoided due to reduced exposure to ground level ozone
- avoided life expectancy loss due to PM2.5 exposure around 230,000 YOLLs
- additional 4.4 thousand km2 would de spared from acidification
- additional 13.3 thousand km2 would be spared from eutrophication
- In monetary terms, the value of avoidable mortality may amount to 460 million EUR due to PM2.5 and 46 million EUR due to ground level ozone in the year 2030 for the EU-28.
- The value of avoided life expectancy loss would stand at immense 26 billion EUR in 2030 for the EU-28

– note: as with all impacts, these are incremental values, difference between the two scenarios of the year 2030.

Energy poverty-related health
According to the European Union's Survey on Income and Living Conditions (EU SILC), 9.4% of European Union's population were unable to keep their homes adequately warm and 15.2% lived in residential housing characterized by a leaking roof, damp walls, floors or foundation, and rot in window frames or floors in 2015. COMBI quantified the energy poverty-related public health impacts in the year 2030 of accelerated building refurbishments between 2015 and 2030 – avoided excess cold weather deaths due to reduced indoor cold exposure and avoided/reduced asthma

due to reduced indoor dampness exposure.

Results are annual impacts in the year 2030, that result from energy efficiency actions throughout Europe leading to energy savings of about 8% relative to a reference scenario.

Depending on scenarios of whether policies are targeted towards socially vulnerable or not at all, the results show that:

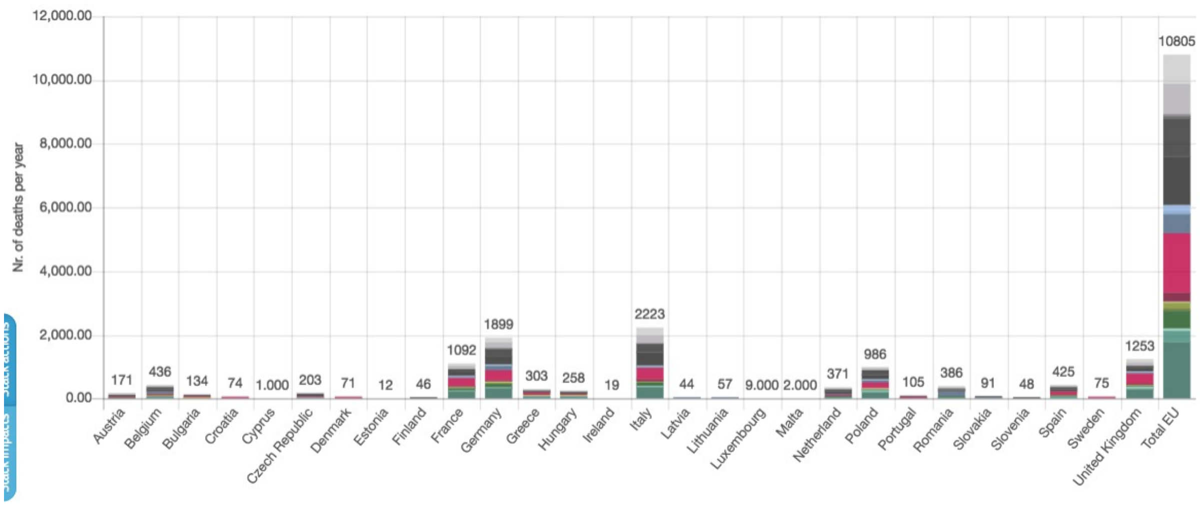
- 3,000–24,000 avoided premature deaths due to reduced indoor cold
- 2,700–22,300 avoided disability-adjusted life years (DALYs) loss of asthma morbidity due to reduced indoor dampness
- The associated economic value of avoided annual public health damage in 2030 ranges from 323 million EUR to 2.5 billion EUR for premature mortality due to indoor cold; and
- from 338 million EUR to of 2.9 billion EUR due to asthma morbidity due to indoor dampness.

D3.4 quantification report on air pollution-related impacts

D5.4 quantification report on energy poverty-related impacts

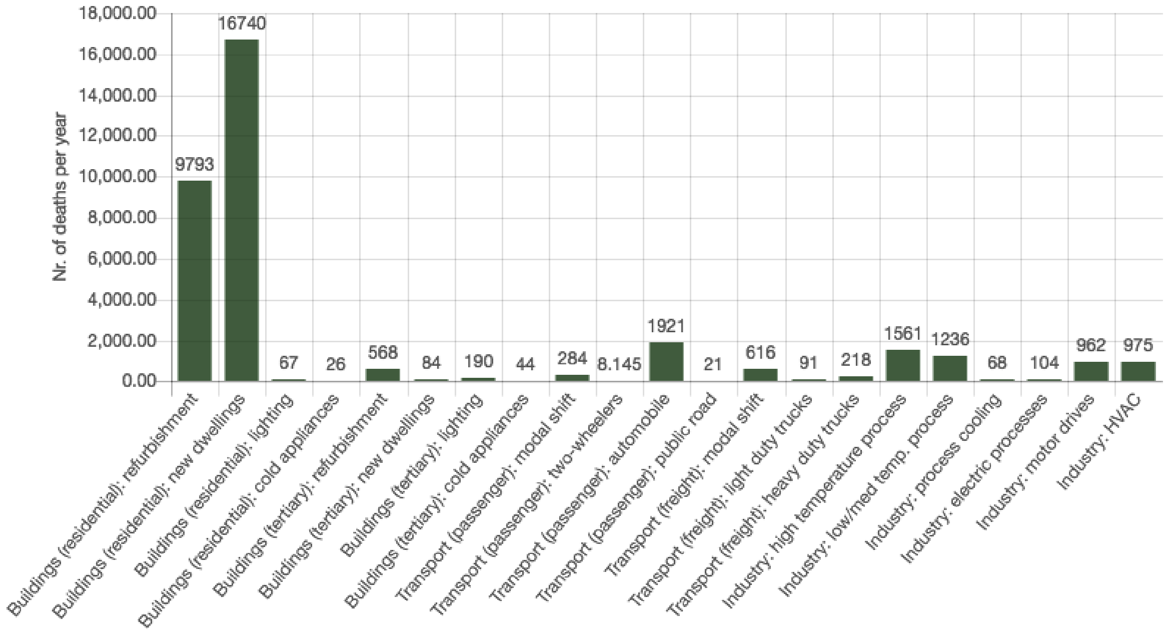
Figure 22 shows that in case of the COMBI efficiency scenario, additional 10,805 premature deaths would be avoided in the year 2030 alone due to reduced exposure to PM2.5 in the EU-28 (see report D3.4)."

Figure 22: Number of avoided yearly deaths (in 2030) due to avoided PM2.5 exposure in the EU-28



View graph in COMBI tool (CBA graph)

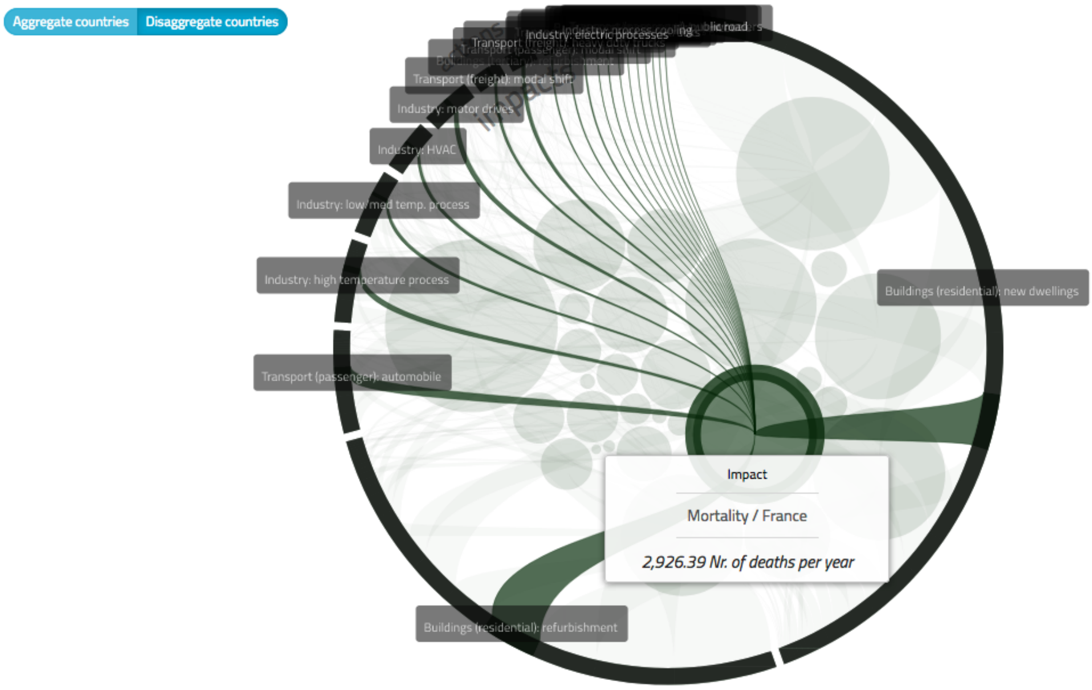
Figure 23: Avoided mortality (nr. of premature deaths per year) due to lower levels of air pollution (ozone and PM2.5) and avoided excess winter mortality due to improved indoor conditions and lower health risks



View graph in COMBI tool (CBA graph)

A relatively small number of deaths is estimated to be avoidable from lower PM2.5 air pollution. This is because air pollution is seldom a single cause of death but rather a contributing factor leading to diseases (see D3.4 report). A relatively large number of deaths is estimated to be avoidable from energy poverty-related health issues due to building indoor conditions that improve with the respective actions and have a strong impact of around 25,000 avoided deaths per year for the whole EU. For all actions, avoidable annual deaths amount to around 35,000. In a "halo" graph, these can be displayed by EU member states (bubbles) and EEI actions (ring) in the COMBI tool (see Figure 24).

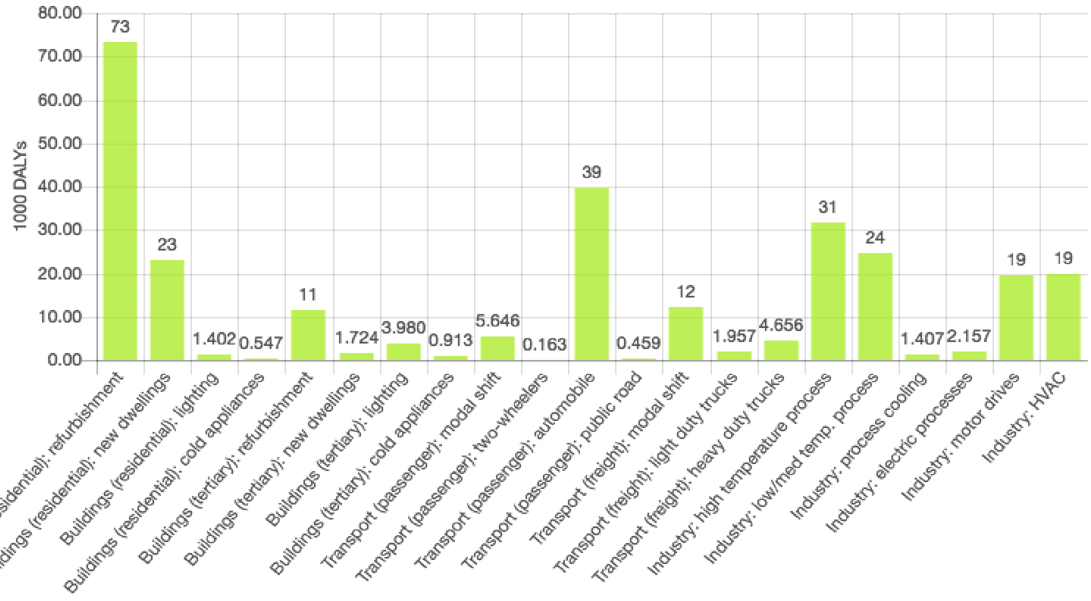
Figure 24: Halo graph of avoided mortality (nr. of deaths per year) due to lower levels of air pollution (ozone and PM2.5) and avoided excess winter mortality due to improved indoor conditions and lower health risks by all COMBI EEI actions (ring) and EU28 member states (bubbles)



[View graph in COMBI tool – online version permits mouse-over information]

In addition to mortality, also morbidity impacts are quantified in disability-adjusted life years (DALY) and years of life lost (YOLL). The aggregated figures from different impact chains (health from better building indoor conditions, from outdoor air pollution and polluted air infiltrating indoors) indicate that EEI actions with high savings of fossil fuels have a strong impact, most prominently building refurbishment and transport, but also industry actions. In total, the loss of 281,000 DALYs (healthy life years) could be avoided.

Figure 25: Overall health impacts measured in gains of healthy life years (DALY) from several causal chains (building refurbishment, indoor/outdoor air pollution)



[View graph in COMBI tool (CBA graph)]

„Air pollution reductions translated into improved air quality and reduced pressures on human and ecosystem health. Premature deaths due to exposure to PM2.5 would decrease by 23% between 2015 and 2030 in the EU-28, or by 66,564 avoided premature deaths in 2030 compared to 2015.

2.6 Labour productivity from building refurbishment and transport: Shifting from non-refurbished to refurbished buildings can mean 4.5 additional annual work-days/person

COMBI quantifications are annual impacts in the year 2030, that result from energy efficiency actions throughout Europe leading to energy savings of about 8% relative to a reference scenario.

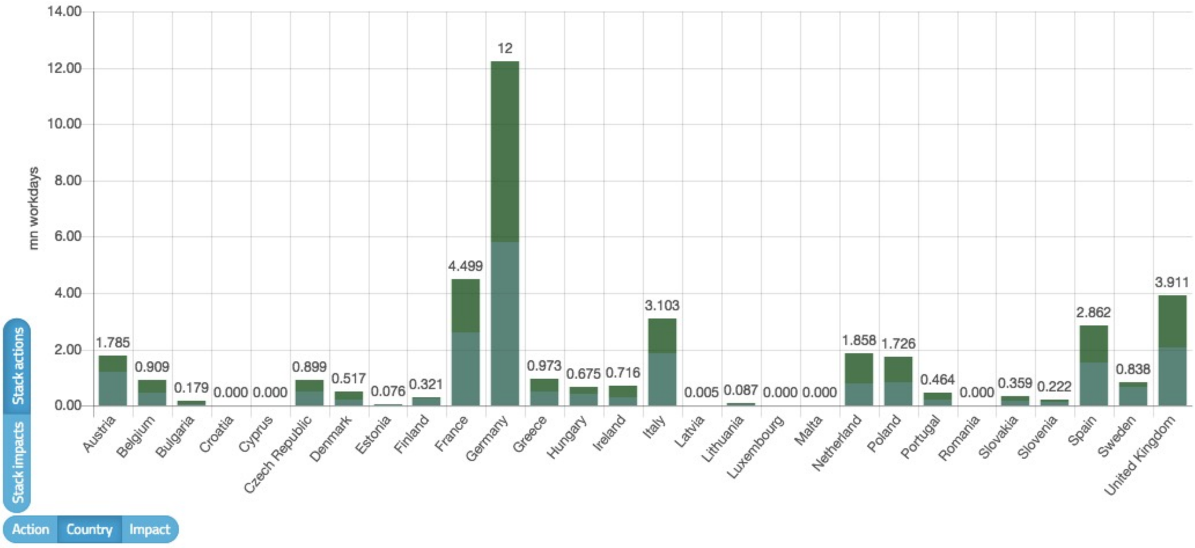
Human productivity following improved health conditions from building refurbishment and transport modal shift are estimated: Several new metrics such as active days, workforce performance and earning ability are proposed to rigorously measure productivity impact of EEI. Accelerated EEI actions between 2015 and 2030 would bring these additional benefits in the year 2030:

- In Europe, on an average 4.5 active work days/person per annum can be gained by having more deeply retrofitted buildings, passive houses, and nearly zero energy buildings.
- In addition, by improving the mental well-being on an average European country can gain around 15.7 million euro/year and on an average 1961 healthy life years per million population per annum can be gained by avoiding exposure to bad indoor air quality and conditions.

By opting for modal shift towards active transportation, on an average 1.6 hours/driver can be saved from traffic congestion in a year. The total amount of time savings quantified by COMBI is however marginal.

More details and D5.4a quantification report

Figure 26: Gain in active days (mn workdays) by EU28 countries



View graph in COMBI tool

2.7 Resource impacts: 850Mt savings of material resources.

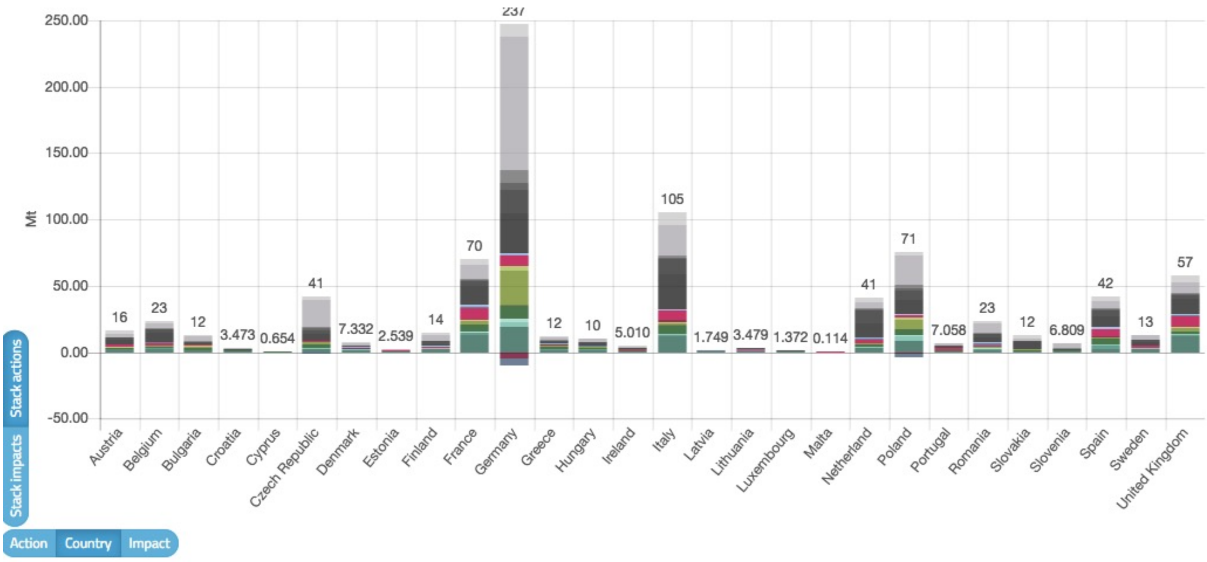
COMBI quantified the material demand from energy efficiency improvements as annual impacts in the year 2030 that result from energy efficiency actions throughout Europe leading to energy savings of about 8% relative to a reference scenario.

Energy efficiency is resource efficiency. More than 850 million tons (Mt) of material do not have to be permanently removed from nature, if Europe implements energy efficiency measures in all sectors.

Yet, there are also resource costs. As an example from the transport sector, roughly 51 million tons of fossil fuels could be saved from improvements in the transport sector alone, but some additional 18 million tons of metal ores are required to provide the necessary transport systems of the future.

More details and full quantification report

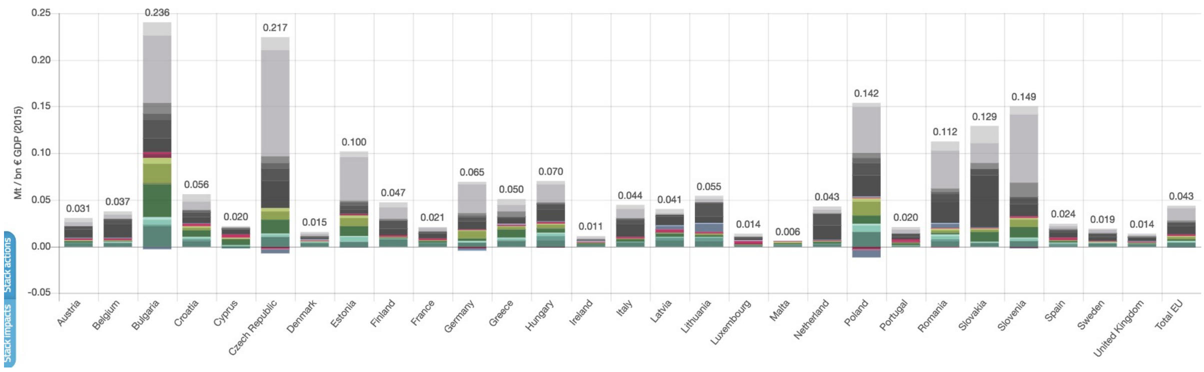
Figure 27: Reduction in material footprint in the EU-28 in Mt



View graph in COMBI tool

Total reduction in material footprint amounts to 850Mt/a in the EU-28. Most resources can be saved from EEI action in the industry

Figure 28: Avoided unused extraction resources in the EU-28 and the total EU per bn€ of 2015 GDP



View graph in COMBI tool

- especially high in the Eastern European Countries
- especially low in WEU countries

2.8 Energy system & security: Savings of more than 250 TWh of electricity generation and 10 bn€ investments in combustion plants

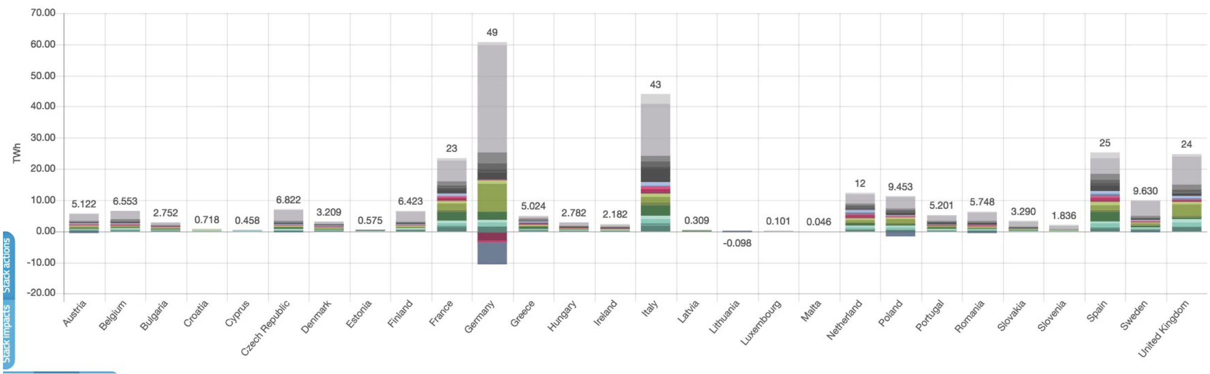
For analysing efficiency impacts on the energy system and energy security, the dedicated COMBI energy balance model was developed and applied. A number of relevant impact indicators were quantified:

- Energy intensity is reduced up to 22 kgoe/1000€ GDP
- The COMBI HHI index measuring energy security through import dependency, diversification of energy sources and geographical diversification improves by up to 5%
- Avoided generation of power from combustibles-based power plants amounts to 257 TWh in the EU and
- avoided investments to these power plants to around 10bn €.

De-rated reserve capacity rate (defined as the reserve capacity of the power sector, divided by its total installed capacity, multiplied by 100) improves in almost all EU countries.

D7.4 quantification report

Figure 29: TWh of avoided electricity generation from combustibles-based power plants

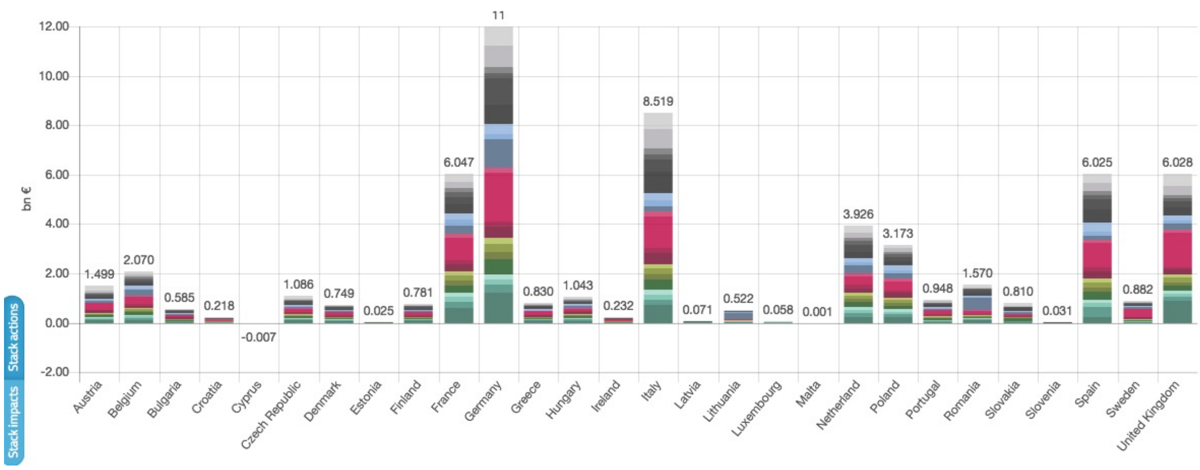


View graph in COMBI tool (CBA graph)

- negative impacts in Germany (additional electricity demand) due to modal shift in passenger and especially freight transport sector

COMBI shows that the additional EEI actions in the COMBI EE scenario would help to reduce fossil fuel import costs from outside EU by almost 60 bn € (for the total EU). In absolute terms, big effects occur in big countries, as Figure 30 shows. The highest per GDP effects occur in Eastern European countries.

Figure 30: Monetized avoided fossil fuel imports from outside EU



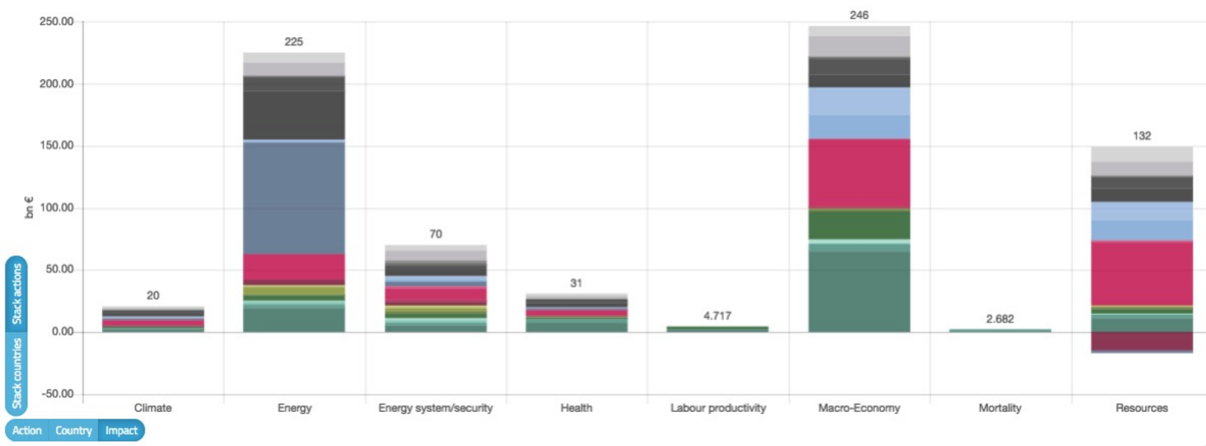
View graph in COMBI tool (CBA graph)

3 Insights from cross-impact analysis

3.1 Comparison of monetized impacts

As discussed above, not all impacts were possible to monetize. All those that could be monetized can be viewed and selected in the “monetary” mode of the tool, irrespective of possible double-counting. Figure 31 illustrates all impacts in monetary values in bn€ and pre-aggregated to 8 impacts categories for the “standard mode” of the tool.

Figure 31: Selected impacts that can be monetised (in bn €) sorted by impact



View graph in COMBI tool (incl. colour legend: EEI impacts)

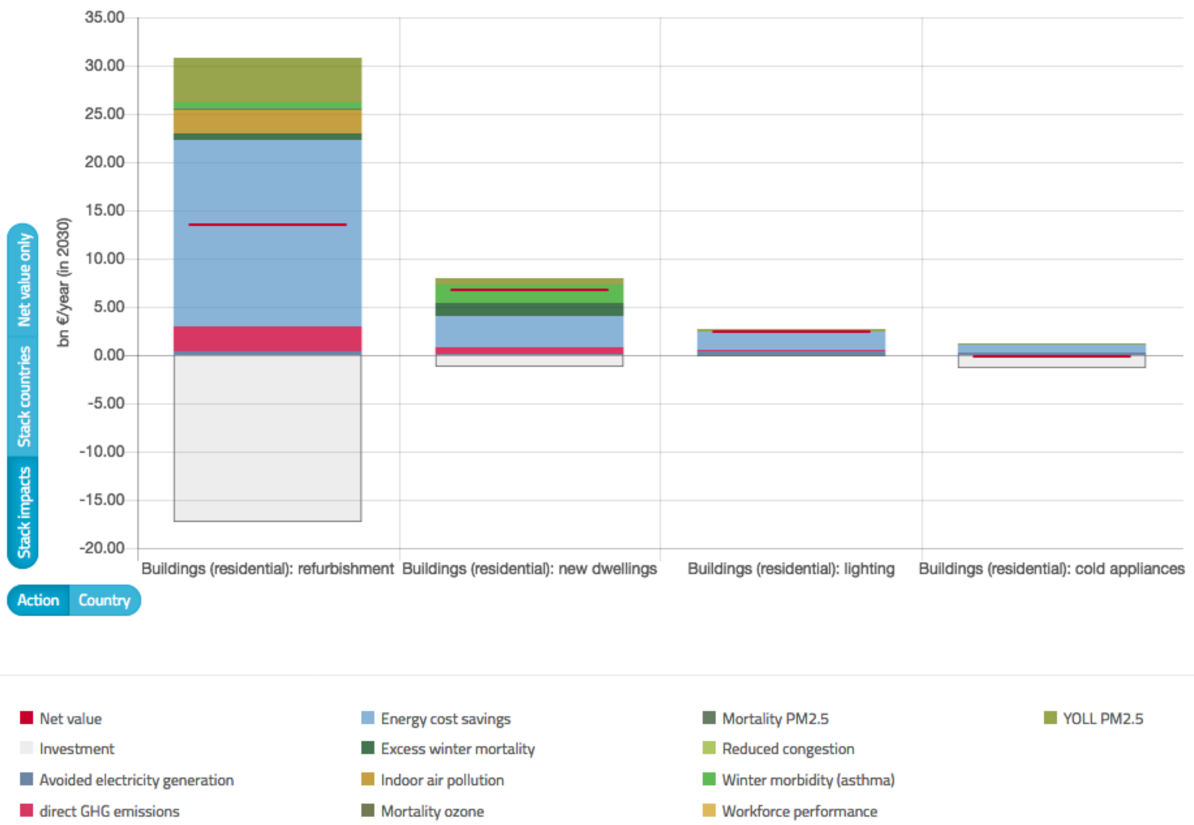
View graph in COMBI tool (disaggregated to individual sub-impacts in expert mode)

3.2 Cost-Benefit Analysis of COMBI EEI actions

As explained above, a significant number of (monetized) impacts overlap with each other or with direct energy cost savings, so possible double-counting needs to be avoided. In COMBI, only impacts with no danger of double-counting (i.e. *additional* impacts) are included in the Cost-Benefit Analysis and the respective mode in the tool. This is a hence very conservative approach.

Based on the user's selection of EEI actions, EU28-member states and impacts, the online tool will execute a calculation of net values resulting from costs (investments) and benefits (energy cost savings and multiple impacts). Details of the calculation are included in the tool documentation (D8.1). Figure 32 shows an example of annualised net present value (red line) for additional[12] EEI actions in the residential buildings sector in the EU28 member states.

Figure 32: Annualised net present value (bn€ per year in 2030) for the refurbishment of buildings in the residential sector



View graph in COMBI tool

View graph in COMBI tool: all EEI actions (except modal shift which cannot be included to CBA due not no availability of infrastructure investment costs and excl. freight transport actions due to outdated investment cost figures)

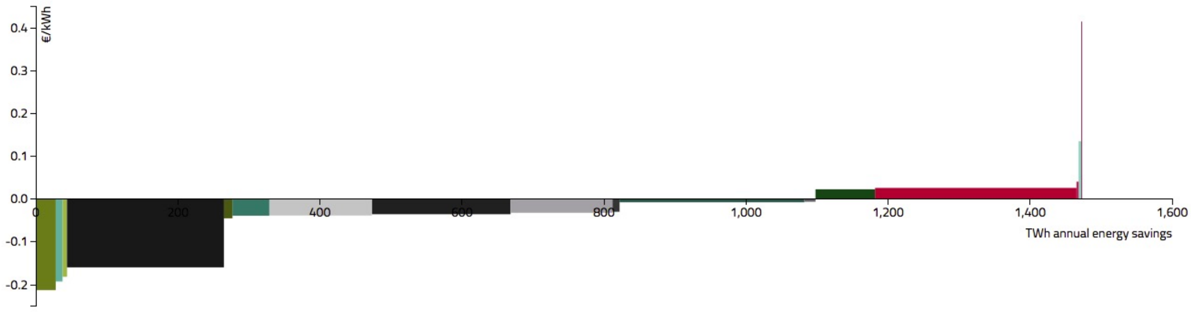
The online tool also offers levelisation of net values by TWh-savings and CO_2eq-savings, i.e. putting the net value per EEI action in relation to energy and GHG emission savings. As a result, the tool offers for each action an indicator of

- net cost per kWh energy saved
- net cost per tCO_2eq mitigated

12Difference between COMBI reference and efficiency scenario.

These are standard indicators often used for comparing energy saving options with energy supply options. Combining these indicators with the savings potential (total kWh or tCO_2eq), they can be turned into marginal cost curves of energy or GHG emission savings (see Figure 33).

Figure 33: Net marginal energy cost savings (total) for EU-28 (excluding multiple impacts) (excluding modal shifts and trucks) (expert mode)

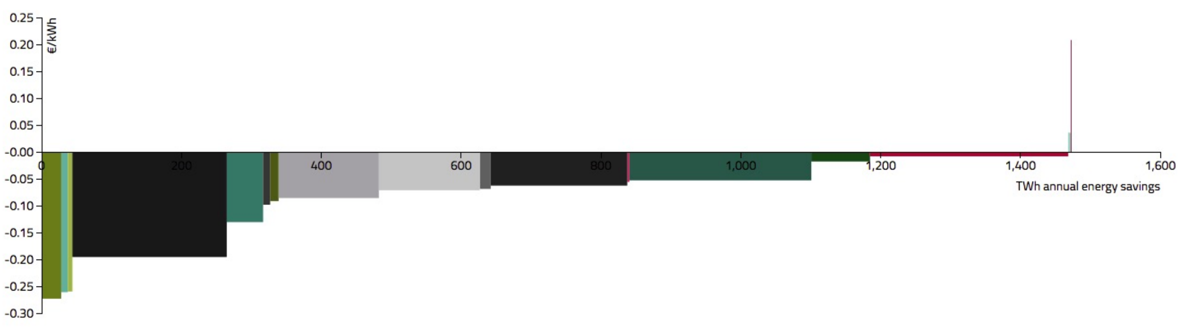


[View graph in COMBI tool]

Note: Because *net costs = costs – benefits* → if *benefits > costs* then net costs are negative → EEI actions are cost effective.

- without MI the following EEI actions are not cost-effective:
  - Buildings (tertiary): refurbishment
  - Transport (passenger): cars
  - Transport (passenger): public roads/buses
  - Buildings (residential): cold appliances
  - Transport (passenger): two wheelers
- no analysis can be undertaken for modal shift and freight transport actions (see above)

Figure 34: Net marginal energy cost savings (total) for EU28 (including multiple impacts) (excluding modal shifts and trucks)



[View graph in COMBI tool] (all EEI actions except modal shifts which cannot be included to CBA due to no availability of infrastructure investment costs and trucks due to unreliability of outdated investment costs)

- incl. MIs most of EEI actions become cost-effective, except for
  - Buildings (residential): cold appliances (COMBI action is A+++ only)
  - Transport (passenger): two wheelers (very costly action, but limited savings potential)

Annex

Table 6: Summary of benefits and costs in CPUC (2008) cost tests

Test	Benefits	Costs
PCT – participant cost test	Benefits and costs from the perspective of the end-use actor installing the end-use action Guiding question: is the end-use action economically attractive for the actor?	
	Incentive payments Bill savings Applicable tax credits or incentives	Incremental equipment costs Incremental installation costs
PACT – program administrator cost test	Perspective of utility, government agency, or third party implementing the program Guiding question: Is energy efficiency cheaper than expansion of energy supply?	
	Energy-related costs avoided by the utility Capacity-related costs avoided by the utility, including generation, transmission, and distribution	Program overhead costs Utility/program administrator incentive costs Utility/program administrator installation costs
RIM – ratepayer impact measure test	Impact of efficiency measure on non-participating ratepayers overall (only for EEOs) Guiding question: Will energy prices increase or decrease?	
	Energy-related costs avoided by the utility Capacity-related costs avoided by the utility, including generation, transmission, and distribution	Program overhead costs Utility/program administrator incentive costs Utility/program administrator installation costs Lost revenue due to reduced energy bills
TRC – total resource cost test	Benefits and costs from the perspective of all citizens in the country (region, municipality...) Guiding question: Will the total costs of energy services in the territory decrease?	
	Energy-related costs avoided by the utility Capacity-related costs avoided by the utility, including generation, transmission, and distribution Additional resource savings (i.e., gas and water if utility is electric) Monetised environmental and non-energy benefits	Program overhead costs Program installation costs Incremental measure costs (whether paid by the customer or utility)
SCT – societal cost test	Benefits and costs to all in the utility service territory, state, or nation as a whole Guiding question: Is the nation (region, city,...) better off as a whole?	
	Energy-related costs avoided by the utility Capacity-related costs avoided by the utility, including generation, transmission, and distribution Additional resource savings (i.e., gas and water if utility is electric); Monetised and non-monetised co-benefits such as cleaner air or health impacts	Program overhead costs Program installation costs Incremental measure costs (whether paid by the customer or utility) Monetised and non-monetised co-costs

Source: National Action Plan for Energy Efficiency (2008), adapted by Wuppertal Institute

Table 7: Energy savings, energy cost savings and annualised investment costs by country

Country	Energy savings (all fuels) in TWh	Additional energy cost savings (bn€/year in 2030)	Additional investment costs (annualised, bn€/year)
Austria	47,48	3,70	2,01
Belgium	61,37	5,68	2,83
Bulgaria	16,04	1,02	0,74
Croatia	7,88	0,48	0,38
Cyprus	1,82	0,12	0,16
Czech Republic	40,18	3,23	1,63
Denmark	19,82	1,99	1,47
Estonia	3,47	0,25	0,15
Finland	37,72	4,00	1,61
France	192,06	16,88	14,12
Germany	307,98	19,44	17,04
Greece	22,15	1,96	1,27
Hungary	25,70	1,79	1,15
Ireland	13,96	1,28	1,27
Italy	227,30	17,68	12,01
Latvia	5,82	0,30	0,21
Lithuania	12,08	0,46	0,34
Luxembourg	4,94	0,37	0,36
Malta	0,34	0,03	0,05
Netherland	95,06	6,50	4,46
Poland	87,09	5,98	5,14
Portugal	21,04	1,77	1,76
Romania	47,79	1,96	1,73
Slovakia	24,03	1,88	1,11
Slovenia	7,88	0,65	0,46
Spain	120,46	12,04	9,00
Sweden	39,99	4,07	2,06
United Kingdom	156,07	15,63	10,07
EU	1647,50	131,15	94,60

Table 8: Energy savings, energy cost savings and annualised investment costs by EEI action

EEI action	Energy savings (all fuels) in TWh	Additional energy cost savings (bn€/year in 2030)	Additional investment costs (annualised, bn€/year)
Buildings (residential): refurbishment	260,26	19,20	17,32
Buildings (residential): new dwellings	51,97	3,24	1,23
Buildings (residential): lighting	9,54	2,00	0,16
Buildings (residential): cold appliances	3,73	0,79	1,29
Buildings (tertiary): refurbishment	83,95	4,31	6,24
Buildings (tertiary): new dwellings	12,05	0,83	0,29
Buildings (tertiary): lighting	28,05	6,07	0,11
Buildings (tertiary): cold appliances	6,44	1,35	0,19
Transport (passenger): modal shift	39,64	0,00	0,00
Transport (passenger): two-wheelers	1,01	0,08	0,50
Transport (passenger): automobile	283,52	20,37	27,73
Transport (passenger): public road	3,00	0,13	0,25
Transport (freight): modal shift	89,56	0,00	0,00
Transport (freight): light duty trucks	13,42	0,70	9,78
Transport (freight): heavy duty trucks	31,74	1,73	11,66
Industry: high temperature process	220,78	39,00	3,82
Industry: low/med temp. process	195,27	11,17	4,31
Industry: process cooling	10,12	0,89	0,59
Industry: electric processes	15,69	0,46	0,36
Industry: motor drives	143,42	10,31	5,74
Industry: HVAC	144,36	8,54	3,02
Total	1647,50	131,15	94,60

Table 9: Summary of results from COMBI quantifications

Impact category	Key findings of COMBI EEI actions in the EU28: annual impacts, incremental values, difference between the two scenarios in the year 2030)	Detailed findings
Energy	Energy savings vs. the reference scenario: around 8%, 1647 TWh/year or 142 Mtoe/year in 2030 (around the "EUCO+33 to +35" scenario)	Energy savings in EU28: highest in Germany (307 TWh), Italy (227 TWh), France (192 TWh) Energy savings by actions: highest from transport: passenger cars (283 TWh), buildings (residential): refurbishment (260 TWh), industry: high temperature processes (220 TWh)
	Energy cost savings: 225 bn€ in 2030	Energy cost savings in EU28: highest in Germany (43 bn€), France (26 bn€), Italy (20 bn€) Energy cost savings by actions: highest from transport (freight): model shift (90 bn€), industry: high temperature processes (39 bn€), transport: passenger cars (20 bn€), buildings (residential): refurbishment (19 bn€)
	Investment cost: 1,072 bn€ [13]	Investment in EU28: highest in Germany (217 bn€), France (149 bn€), Italy (132 bn€) Investment by actions: : highest in transport: passenger cars (331 bn€), buildings (residential): refurbishment (302 bn€), buildings (tertiary): refurbishment (109 bn€)
Air pollution	Avoided PM2.5 emissions in 2030 in EU-28: 65.5 ktons per year Avoided PM10 emissions in 2030 in EU-28: 78.3 ktons per year	Countries with especially high PM2.5 avoidance: Italy, Poland and the UK, followed by the largest countries France and Germany. In Italy 9,200 kt PM2.5 could be avoided, half of the EEI actions are in the industry sector. In other EU countries, avoided PM2.5 emissions are more evenly distributed between sectors.
	Avoided SO2 emissions in 2030 in EU-28: 210.9 ktons per year	Avoided SO2 emissions (per GDP): highest in EEU countries; especially low in WEU countries; highest in Bulgaria due to actions in the transport and industry sector
	Avoided VOC emissions in 2030 in EU-28: 170.5 ktons per year	Avoided VOC emissions (per GDP): especially high in Eastern European and Baltic Countries; highest in Latvia, Bulgaria, Slovenia, Estonia
	Avoided NOX emissions in 2030 in EU-28: 316.9 ktons per year	
Ecosystem degradation	Area affected by acidification: additional 4.4 thousand km2 spared (additional reduction of 4%)	Largest area affected by reduced acidification in Sweden, Poland, Germany
	Area affected by eutrophication: Additional 13.3 thousand km2 spared (additional reduction of 1%)	Largest area affected by reduced eutrophication in Italy, France, Austria, High avoided eutrophication effects (per GDP): in Estonia due to different EEI actions especially in the buildings and transport, but also in the industry sector
Energy system/ security	Energy intensity: reduced by up to 22 kgoe/1000€ GDP	Energy intensity improvements relative to the reference case for the EU member states vary from roughly 10% to 15%, reflecting the different energy savings similar COMBI actions may realize in the different countries.
	COMBI HHI index (measuring energy security through	Some EU member states improve their energy security

13Investment costs for all EEI actions except modal shifts which cannot be included to CBA due to no availability of infrastructure investment costs and trucks due to unreliability of outdated investment costs.

	import dependency): diversification of energy sources and geographical diversification improves by up to 5%	as a result of the COMBI actions, while others appear to be worse off, mainly due to decreased net diversification effects.
	Avoided generation of power from combustibles-based power plants: 257 TWh in the EU; avoided investments to these power plants: around 10bn €	Avoided electricity generation from combustibles-based power plants: additional electricity demand in Germany due to modal shift in passenger and especially freight transport sector Only in Lithuania slightly higher costs for combustibles-based power plants (4 Mio. €) due to an increase in gas based powered plants, all other EU countries benefit (avoided costs) due to a decrease in required generation capacity.
	De-rated reserve capacity rate (defined as the reserve capacity of the power sector, divided by its total installed capacity, multiplied by 100): improves in most EU countries	Note: For EU member states with an already fairly high reserve capacity rate, an increase may not be optimal from an economic point of view.
	Monetized avoided fossil fuel imports from outside EU: reduced fossil fuel import costs from outside EU by almost 60 bn € (for the total EU).	In absolute terms, large effects occur in big countries. The highest per GDP effects occur in Eastern European countries.
Labour productivity	Gain of 4.5 active work days/person per annum by having more deeply retrofitted buildings, passive houses, and nearly zero energy buildings	
	By improving the mental well-being an European country can on average gain around 15.7 million €/year and 1961 healthy life years per million population per annum by avoiding exposure to bad indoor air quality and conditions	
	By opting for modal shift towards active transportation, 1.6 hours/driver can on average be saved from traffic congestion per year	
Mortality	Avoided premature mortality due to PM2.5: additional 10,805 premature deaths avoided in the EU-28 due to reduced exposure to particulate matter, monetary value of avoidable mortality: 460 million EUR exposure in 2030 for the EU-28	Number of avoided yearly deaths (in 2030) due to avoided PM2.5 exposure highest in Italy, Germany, UK, France
	Avoided life expectancy loss due to PM2.5 to the surviving population in 2030: 230,226 YOLLs and immense 26.41 billion EUR for the EU-28	Avoided life expectancy loss due to PM2.5 highest in Italy, Germany, France
	Ground level ozone: additional 442 deaths would be avoided due to reduced ozone exposure, monetary value of avoidable mortality: 46 million EUR due to reduced ground level ozone exposure in the year 2030 for the EU-28	Number of avoided yearly deaths (in 2030) due to reduced ozone exposure highest in in Italy, Germany, United Kingdom, France
	Avoided excess cold weather deaths due to indoor cold exposure: 3,000–24,000 avoided premature deaths	
Climate	Avoided EU carbon footprint (including 150 Mt CO2eq indirect upstream emissions): 509 Mt CO2eq of reduced global GHG emissions	Especially high impacts per GDP in Eastern European countries high impacts per 2015 GDP from transport and industry sector
	Avoided direct GHG emissions (from fuel combustion): 362 Mt CO2eq annually	Especially high impacts per GDP in Eastern European countries high impacts per 2015 GDP from transport and industry sector

Health/morbidity	In total, 281,000 DALYs could be gained.	The aggregated total DALY (healthy life years) figures from different impact chains (health from better building indoor conditions, from outdoor air pollution and polluted air infiltrating indoors) indicate that EEI actions with high savings of fossil fuels have a strong impact, most prominently building refurbishment and transport, but also industry actions.
	Winter morbidity (asthma): 2,700–22,300 disability-adjusted life years (DALYs) of asthma morbidity can be avoided due to indoor dampness	
	Economic value of avoided annual public health damage in 2030: 338 million EUR to of 2.9 billion EUR due to asthma morbidity due to indoor dampness	
Macro-economy	Short run positive macro-economic stimulus on the economy: 0.9 per cent of EU's GDP and a positive effect on the labour market of 2.3 mn job-years. This stimulus will only materialise in countries with idle resources in 2030 that can support further growth (negative output gap, situation of economic downturn). In 2018, about half of the EU28 Member States are expected to have a negative output gap.	Short-term increase in GDP for the EU28: mainly induced from buildings and actions in the transport sector (actions with high investment values) Largest number of jobs: from EEI actions with high investment values and implemented in labour-intensive sectors: buildings (residential and tertiary) and transport sector Total employment and GDP effects: larger for bigger countries Increase in GDP as % of GDP: especially Eastern European Countries see larger GDP increase
	Long run effects: CGE modelling shows no significant impacts on employment and even slightly negative impacts on GDP. Reduction in CO2 emissions and significantly lowered carbon allowance and fossil fuel prices due to EE improvements, which, given all EU countries are net fossil fuel importers will also improve their terms of trade.	Fossil fuels prices in the EU: decrease by 1-3% compared to a current policies scenario Global price on crude oil: falls by 1% Coal and gas prices in the EU: reduced by 2% and 3% respectively
	Public budget effect: While public investment or subsidies imply higher public spending, there is also potential for cost savings with improved EE in the public sector. In addition, the employment and output effects mentioned above bring about an increase in tax revenue	Public budget effect (in absolute terms): highest in the larger EU countries France, Germany, Italy, Spain and the United Kingdom Public budget effect (expressed per GDP): more evenly distributed among EU28, rather high for EEU countries, and lower for CEU countries Public budget effect in 2018: range from 0.06% (Bulgaria) to 0.56% (Finland) of GDP. Public budget effect in 2030: largest in the Netherlands, Italy and Portugal with 0.64% of GDP in all these countries (assuming a sufficiently negative output gap in all countries). Smallest budget effect in Luxembourg and Greece with less than 0.3% of GDP
Resources/ material footprint	Material Footprint: net savings of 868 Mt of materials	Avoided unused extraction resources per bn€ of 2015 GDP: especially high in the Eastern European Countries (highest in Bulgaria and Czech Republic), especially low in WEU countries
	Differences in the production systems (production phase) for vehicles and lighting systems require additional 11.2 Mt of resources (partial use phase compensation), but also lead to additional Carbon Footprint savings of 8.7 Mt (overall savings).	